GRAPHICAL USER INTERFACE CUSTOMIZATION FOR THE ELDERLY IN AMBIENT ASSISTED LIVING ENVIRONMENTS

by

Mustafa Torun

B.S., Computer Engineering, Boğaziçi University, 2009

Submitted to the Institute for Graduate Studies in

Science and Engineering in partial fulfillment of

the requirements for the degree of

Master of Science

Graduate Program in Computational Science and Engineering

Boğaziçi University

2012

GRAPHICAL USER INTERFACE CUSTOMIZATION FOR THE ELDERLY IN AMBIENT ASSISTED LIVING ENVIRONMENTS

APPROVED BY:

Prof. Can Özturan. . . . . .
(Thesis Supervisor)

Prof. Cem Ersoy . . . . . .
(Thesis Co-Supervisor)

Assist. Prof. Mutlu Koca. . . . . .

Assist. Prof. Albert Ali Salah. . . . . .

Assoc. Prof. Tuna Tuğcu. . . . . .

DATE OF APPROVAL:

This thesis is dedicated to my "dear".

ACKNOWLEDGEMENTS

I would like to thank my thesis supervisor Prof. Can Özturan because of his acceptance of my M.S process and his valuable contributions. Furthermore, I would like to express my sincere gratitude to my thesis co-advisor Prof. Cem Ersoy who has continuously supported my M.S study and research for his patience, motivation, enthusiasm, and immense knowledge. I could not have imagined having a better advisor and mentor for my M.S study.

Besides my advisors, I would like to thank to the other members of my thesis committee, Assoc. Prof Tuna Tuğcu, Assist. Prof. Albert Ali Salah and Assist. Prof. Mutlu Koca, because of their valuable time, insightful comments and hard questions.

I am deeply grateful to Dr. Tim van Kasteren who has a great patience and did not give up answering my sequence of questions. This thesis would not have been possible unless he did not patiently encourage me and direct me during my research and study. I have learned so much from him.

I also would like to thank Dr. Özlem D. Incel because of her valuable time and help. She patiently continued to read my thesis drafts several times and I continuously tried to handle her red lines over my thesis like the yellow marks of Tim.

I thank my fellow officemates, Hande, Remzi, Bilgin and Rabun because of their instant and worthy helps and because of the pretty working hours in the office. Furthermore, I also want to thank my dear friend Osman Melih Dalca who helped me during the experiments in the elderly care facility.

The financial support of the Bogazici University is gratefully acknowledged.

Finally, my great thanks are to my dear family.

This research is supported by BAP under the grant number 6370.

ABSTRACT

GRAPHICAL USER INTERFACE CUSTOMIZATION FOR THE ELDERLY IN AMBIENT ASSISTED LIVING ENVIRONMENTS

With the help of the graphical user interfaces (GUI), young people or everyday-computer-users can easily get accustomed to the various digital devices. However, acceptability of GUIs by elderly, as the rapidly growing group of today´s population, is a challenging issue due to their little experience with technology and experienced impairments at different levels, such as visual, audial, psychomotor and cognitive impairments. Providing simplicity for user interfaces in order to be acceptable by elderly people is the main concern of the studies that try to address this challenge. Thus, designing simple and hence acceptable user interfaces for elderly requires considering their preferences and impairments. In this thesis, we study GUIs for elderly people with different impairments in the context of in-home healthcare system that involves daily living monitoring, focusing on the relation between two main design parameters of a graphical user interface: page complexity which is the number of interface elements on each page and the page hierarchy which is the number of the pages to be traced in order to finish a task. In order to study the dichotomy between these two phenomena, we designed two versions of the interface: One version is the flat version which has less page hierarchy with more complex pages and the other version is the deep version which has deeper page hierarchy with less complex pages. We conducted experiments with 18 elderly people having different impairments in order to understand whether the flat version or the deep version would be more acceptable. We asked them to complete some tasks such as making a video-call to a friend and setting a reminder to the agenda. Using the errors, time, inter-touch time between two consequent interactions, key strokes and clicks as the experiment metrics, the results revealed that the flat version with a reasonable complexity level would be more acceptable by elderly.

ÖZET

ÇEVRE DESTEKLİ ORTAMDA, YAŞLI TERCİHLERİNE GÖRE GRAFİKSEL KULLANICI ARA YÜZÜ TASARIMI

Grafiksel kullanıcı arayüzleri (GKA) sayesinde, gençler ve günlük kullanıcıların çeşitli dijital aletlere alışması oldukça kolay olmaktadır. Oysa, bu GKA'ların, hızla büyüyen bir kitle olan yaşlılar tarafından kabul edilebilirliği önemli bir mesele olarak karşımıza çıkmaktadır. GKA'ların yaşlı kullanıcılar tarafından kabul edilebilirliğini arttırmak için arayüzlere basitlik ve sadelik kazandırmak bu alanda yapılan çalışmaların ana temasını teşkil etmektedir. Dolayısıyla, yaşlılar tarafından kabul edilebilecek arayüzlerin tasarlanması, yaşlıların önceliklerinin ve görsel, işitsel, bedensel ve zihinsel engellerinin temel tasarım parametreleri olarak göz önünde bulundurulmasını gerektirmektedir. Bu tezde, çevre destekli ev-içi sağlık gözetimi ortamında yaşlılar için GKA tasarlanması problemi üzerinde bir çalışma gerçekleştirilmiştir. Gerçekleştirdiğimiz literatür taraması, görsel, işitsel ve psikomotor bozuklukların birçok arayüz tasarım süreci tarafından ele alınıp çözümler üretildiğini fakat bilişsel bozukluklar kısmının ise genelde "sayfa karmaşıklığını azaltmak" olarak ele alındığını göstermiştir. Bu tezde ise, bir GKA'nın iki temel parametresi arasındaki ilişki üzerinde yoğunlaşılmıştır: bir sayfadaki arayüz elemanlarının yoğunluğu olarak ifade edilebilecek sayfa karışıklığı ve bir işlemi bitirebilmek için taranması gereken sayfa sayısı olarak açıklanabilecek sayfa hiyerarşisi. Bu iki fenomen arasındaki ikilik üzerinde çalışabilmek için iki farklı arayüz geliştirilmiştir: birincisi, sayfa sıradüzeni düşük olan fakat sayfa karmaşıklığı nispeten fazla olan sürüm, ikincisi ise sayfa karmaşıklığı düşük fakat sıradüzeni nispeten büyük olan sürüm. Deneyler için, farklı engelleri olan 18 yaşlı ile çalışılmıştır. Hata oranı, toplam zaman, iki tıklama arasında geçen zaman, klavye kullanımı ve tıklama sayısı metrik olarak kullanılmış ve sonuçlar makul bir karmaşıklığa sahip olacak şekilde birinci sürümün daha iyi, yaşlılar tarafından daha kullanılabilir olduğunu göstermiştir.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS iii
ABSTRACT iv
ÖZET v
LIST OF FIGURES viii
LIST OF TABLES x
LIST OF SYMBOLS xi
LIST OF ACRONYMS / ABBREVIATIONS xii
1. INTRODUCTION 1
2. MOTIVATION: GUI DESIGN FOR ELDERLY HOMECARE APPLICATIONS 4
2.1. Pervasive Healthcare and GUI 4
2.2. Elderly Impairments and GUI 5
3. RELATED WORK 7
3.1. Color and Contrast 7
3.2. Interface Elements, Fonts and Interaction Types 10
3.3. Reminder Design 12
3.4. Interactive Sentences 13
3.5. Menu Design 14
3.6. Two Ways of Presenting an Interface 18
3.7. Conclusion 20
4. GUI APPLICATION: FLAT AND DEEP VERSIONS AND FUNCTIONALITIES 22
4.1. Complexity and Page Hierarchy 23
4.2. Functionalities of the Application 24
4.2.1. Agenda 25
4.2.2. Messaging 26
4.2.3. Video-calling 27
4.2.4. Medical Activity 28
4.3. Implementation 29
5. EXPERIMENT DESIGN 31
5.1. Experiment Setting 31

5.2. Requirements of Test Subjects 32
5.3. Task Specifications 33
5.4. Measures 34
5.5. The Experiments 34
5.6. Experiment Results 35
5.6.1. Subjective Metrics 36
5.6.2. Objective Metrics 42
6. ENHANCED VERSION OF OUR APPLICATION 54
6.1. Medical Activity Enhancement 54
6.2. Reminders Enhancement 55
6.3. Homepage Information Enhancement 56
6.4. Interactive Sentences Enhancement 56
7. DISCUSSION 58
7.1. Findings 58
7.1.1. Contact with Elderly 58
7.1.2. Understanding the Elderly 58
7.2. The Interaction Metaphors 59
7.2.1. Touching 59
7.2.2. Buttons 60
7.2.3. Interactive Sentences 60
7.2.4. Arrangement of Interface Elements 61
8. CONCLUSION AND FUTURE WORK 63
APPENDIX A: PROVIDED LEAFLET 66
APPENDIX B: QUESTIONNAIRE AND INTERVIEW 67
APPENDIX C: RECORDING USER INPUT (RUI) PROGRAM 72
APPENDIX D: FORMULAS 75
APPENDIX E: BLUETOOTH PROGRAMMING 77
REFERENCES 80

LIST OF FIGURES

Figure 3.1. COGKNOW Homepage. 8
Figure 3.2. COGKNOW Reminder Display. 9
Figure 3.3. MPOWER Homepage. 9
Figure 3.4. SOPRANO full screen reminder. 13
Figure 3.5. SOPRANO reminder as subtitle. 13
Figure 3.6. HERMES myPast (2008). 15
Figure 3.7. HERMES main page (2008). 15
Figure 3.8. HERMES myPast (2011). 16
Figure 3.9. HEPHAISTOS main page. 16
Figure 3.10. SOPRANO Homepage. 17
Figure 3.11. Graphical Example for Complexity versus Hierarchy. 19
Figure 4.1. Home Page of our Application. 25
Figure 4.2. A screen from Agenda functionality (Flat version). 25
Figure 4.3. A screen from Agenda functionality (Deep version). 26
Figure 4.4. A screen from Messaging functionality (Flat version). 26
Figure 4.5. A screen from Messaging functionality (Deep version). 27
Figure 4.6. A screen from Video-calling functionality. 27
Figure 4.7. A screen from Medical functionality. 28
Figure 4.8. Example task sequence on flat and deep versions (setting a reminder). .. 29
Figure 5.1. Touchscreen device used for experiments. 32
Figure 5.2. Computer usage of the subjects. 37
Figure 5.3. Internet usage of the subjects. 38
Figure 5.4. Computer usage comfort. 38
Figure 5.5. Evaluation of tasks. 38
Figure 5.6. Evaluation of touchscreen. 39
Figure 5.7. Evaluation of the text sizes. 39
Figure 5.8. Finding the target. 40
Figure 5.9. Overall performance evaluation. 40
Figure 5.10. Average Error. 44

Figure 5.11. Average Time (sec). 44
Figure 5.12. Average Inter-touch Time (sec). 45
Figure 5.13. Average Clicks. 46
Figure 5.14. Average Keystrokes. 47
Figure 5.15. Average Clicks + Keystrokes. 47
Figure 5.16. Errors for the repetition test (flat version users). 50
Figure 5.17. Time (sec) for the repetition test (flat version users). 50
Figure 5.18. Inter-touch time (sec) for the repetition test (flat version users). 50
Figure 5.19. Clicks for the repetition test (flat version users). 51
Figure 5.20. Keystrokes for the repetition test (flat version users). 51
Figure 5.21. Errors for the repetition test (deep version users). 52
Figure 5.22. Time (sec) for the repetition test (deep version users). 52
Figure 5.23. Inter-touch time (sec) for the repetition test (deep version users). 52
Figure 5.24. Clicks for the repetition test (deep version users). 53
Figure 5.25. Key strokes for the repetition test (deep version users). 53
Figure 6.1. Using Pulse-oximeter. 54
Figure 6.2. Graphical display of pulse rate results. 55
Figure 6.3. Home page with visual reminders. 56
Figure 7.1. Triangular arrangement of interface elements. 61
Figure C.1. RUI 2.03 Interface. 72
Figure C.2. RUI Log File (txt) with relative. 73
Figure C.3 RUI Log File (txt) with absolute. 74
Figure E.1. C++ code for Pulse-oximeter communicating via the Bluetooth. 79

LIST OF TABLES

Table 4.1. Page Complexity and Page Hierarchy Indices of Two Versions. 24
Table 5.1. Objective Metrics Results. 43
Table 5.2. F-Values of Three Tasks Based on Five Metrics for Both Versions ($F_{(0.05, 1, 14)}$). 48

LIST OF SYMBOLS

C_t	Complexity index of the task t
C	Complexity index of the interface
H_t	Hierarchy index of the task t
H	Hierarchy index of the interface
x_i	Number of interface elements on the page *i*
p_t	Number of pages required to complete a particular task *t*.

LIST OF ACRONYMS / ABBREVIATIONS

ANOVA	Analysis of variance
COGKNOW	Helping people with mild dementia
GUI	Graphical User Interface
HCI	Human Computer Interaction
HD	High Definition
HEPHAISTOS	Home Environment Private Help AssISTant fOr elderly and diSabled
LCD	Liquid Crystal Display
MPOWER	Middleware Platform for eMPOWERing Cognitive Disabled and Elderly
PDA	Personal Digital Assistant
POCA	Proof of Concept Application
RUI	Recording User Input
SOPRANO	Service-oriented Programmable Smart Environments for Older Europeans

1. INTRODUCTION

It is a common observation that the world has become computerized. Not only in the office but also in daily life, we can easily face computerized devices, ranging from personal computers to electronic device panels such as automated teller machines or even washing machines. As a whole, our society is required to be able to operate them with an efficient interaction. After 1980s, manipulating the computerized devices via graphically displayed user interfaces became popular because of their ease of use compared to text-based interfaces which manipulate the computers via text commands. Today, almost all computerized devices are controlled by graphical user interfaces (GUI). For most people, the adaptation to computers with the help of those user interfaces comes quite naturally, but mainly for elderly this adaptation is challenging because they usually have little experience with computers and they have a variety of impairments such as visual, psychomotor, hearing or cognitive impairments [1]. In order to overcome this challenge, the computerized systems might be displayed in a proper way regarding those impairments leading to the acceptance by the elderly people. This will increase the acceptance of those systems by elderly people which is a rapidly growing group of today's world population.

At the same time, the percentage of elderly population is increasing, especially in the developed countries, and will become about 20% of overall population in 2050 [2–4]. As the population of elderly increases, many computer-based solutions are proposed to help elderly in their aging process [5–9].

Considering both the increased number of computerized devices in daily life and the increase in elderly population who have limited skills in using computers, one can say that, a computer interface designed specifically for the elderly could significantly improve the acceptance of such computer systems [9, 10]. In this thesis, we study the acceptance of computer interfaces by elderly.

Most of the studies which include the subject of computerized systems for elderly care focus on one of the particular issues, such as daily living monitoring, location tracking, medication intake monitoring, medical status monitoring, and fall and movement

detection [11–14]. Indeed, a significant number of these projects do not consider the impact of the graphical user interface, which is very important for the overall acceptance of the system. However, with developing technology, people have started to face the need to handle several types of graphical user interfaces for various purposes such as banking services, communication or information search. As the information society and technology develops rapidly, efficiently designed high quality graphical user interfaces become more important and dominant for applications developed for elderly [15]. Thus, it is an inevitable consequence that a computer-based system developed for elderly needs to have an efficient graphical user interface in order to be usable, and hence, acceptable by enabling users to communicate with the whole system.

In addition to the requirement of having a graphical user interface, the interface should be simple considering the physical and cognitive impairments of elderly, in order to be acceptable for elderly [16, 17]. In general, simplicity of a user interface, which is one of the basic issues of design processes, is provided as the main solution to cognitive and physical handicaps [16, 18–20]. The literature, the simplicity is mostly considered as not to display very complex pages with many interface elements such as buttons, text and links at the same time which may cause a cognitive overload [21, 22]. In this thesis, we investigate the goal of providing simplicity as the dichotomy between the "complexity", which means the level of interface elements such as buttons, text and links on a page, and the "page hierarchy", which means the number of different pages a user interacts via GUI in order to complete a task. In other words, we concentrate on providing simplicity by studying the trade-off between reducing the complexity and increasing the page hierarchy by focusing on the following question "*would an interface with several interface elements on each page but having less hierarchy or an interface with less interface elements on each page but having deeper hierarchy would be more acceptable for elderly people?"*

For this purpose, we designed two versions of interfaces of a homecare application to be experimented by elderly. One version is the flat version which has less page hierarchy with more complex pages, i.e., having several interface elements, and the other version is the deep version which has deeper page hierarchy with less complex pages, i.e., having less interface elements. By experimenting with these two interfaces, we get insights about the relationships between page hierarchy and page complexity which are two important parameters of providing simplicity for elderly people.

The rest of the thesis is organized as follows: Chapter 2 is about our motivation introducing the context in which we study the acceptance of GUI by elderly. Chapter 3 is the related work which details the existing graphical user interfaces developed for elderly homecare usage and the implications of these approaches to our study. Chapter 4 describes our application. We explain the common features for user interfaces gathered from several related studies, the functionalities of our application and the complexity versus page hierarchy dichotomy for providing the simplicity. Chapter 5 explains our experimental setup. We include the interpretation of experimental results in this chapter, following with Chapter 6 where the enhanced version of our application according to the test results is explained. The discussion is in Chapter 7 and finally, we have the conclusion and the future work in Chapter 8.

2. MOTIVATION: GUI DESIGN FOR ELDERLY HOMECARE APPLICATIONS

The increase in older population and the consequent rise of chronic and cognitive disorders result in an increase of emergency hospitalized cases and even deaths [23, 24]. Besides, shortage of skilled caregivers and high cost of healthcare make it difficult to provide quality care for elderly. Hence, this situation brings up the need for providing computerized quality care to the elderly and also the challenge of the trade-off between the quality and the costs of the care for the rapidly growing number of the elderly. Currently many in-home technology solutions are entering the market to assist elderly for living in their homes independently. In this regard, in-home pervasive healthcare which involves computer-based technologies appears to be one engaging application in order to address this trade-off.

2.1. Pervasive Healthcare and GUI

Pervasive healthcare can be defined as the healthcare to anyone, anytime, and anywhere by removing locational, time and other restraints while increasing both the coverage and the quality of healthcare where hospital services are not needed [25]. It can provide users, namely the elderly and the caregivers, with continuous medical monitoring, emergency handling, cognitive assistance and medical data access [14]. For example, Wireless Enhanced Care (WeCare) project [26], by our group, is carried out for remote healthcare monitoring of the elderly and the children. With the help of different sensing modalities such as RFID and video, WeCare application senses the environmental context information and monitors the home and the people in it with a high success. However, its interface is designed for monitoring the house by an external end user such as relatives or health professionals but not by the elderly themselves.

We can define GUI as the user interface that enables users to interact with any electronic device with the help of graphical units such as pictures, images or icons rather

than text commands [27]. With new pervasive-healthcare technologies, graphical user interfaces can play a significant role in assisting the elderly people in smart home healthcare systems [28]. In-home pervasive healthcare systems give some feedbacks; remind some relevant events to the user, show some alerts which need inputs or interaction from/with the user or provide some solutions for solitude of elderly such as messaging and videoconferencing. Hence, the graphical user interface is a building block of in-home healthcare systems. Therefore, supporting the graphical user interface design processes becomes a critical issue for in-home pervasive healthcare system designers [15]. On the other hand, one of the most challenging problems for in-home pervasive healthcare projects has been designing graphical user interfaces which are often not well-suited for usage of the elderly with less experience in technology and technological devices and usually having a large variety of physical and cognitive disabilities. Because of these reasons, in this study, we choose to research on graphical user interface acceptance for the elderly in an in-home pervasive healthcare environment scenario.

2.2. Elderly Impairments and GUI

There are a number of studies on graphical user interface customization for elderly usage in smart homes [29–32]. Besides several prototypes of graphical user interfaces, there are commercially available products developed for elderly homecare [14].

When several approaches are investigated, we observe that most of them strongly focus on elderly impairments and possible implications of those impairments for interface design processes. Elderly people usually have various impairments such as visual, psychomotor, hearing or cognitive impairments. Moreover, designers should also consider elderly people with less experience of technological devices. Taking these considerations into account, there is a broad literature about the size of interface elements, color, contrast, page organization and loud range specifications for an acceptable user interface designed for elderly homecare. On the other hand most of the existing designs consider, individually, few design specifications implied by elderly impairments. They consider generally two or three parameters for customization in order to be acceptable [19, 21, 31, 33]. However, for an interface to be accepted by elderly users, it requires to comprehend

all obstacles and their design implications need to be comprehended. For instance, cognitive impairments of elderly are neither considered sufficiently by significant number of designs nor solutions are restricted to just being simple [1, 24, 34, 35]. In our literature survey, explained in Chapter 3, we did not encounter extensive studies and experiments on cognitive implications for graphical user interface design. We elaborate on this issue in Chapter 3.

3. RELATED WORK

With the technological improvements after 90s, human-computer interaction has been held by graphical user interfaces with a growing tendency. Hence, one should consider graphical user interface design processes on one hand and on the other hand the elderly people's cognitive, psychomotor, visual and hearing impairments and their less experience of technology usage.

There are several projects carried out for elderly people in order to provide them a long-life environment by addressing their needs via pervasive healthcare applications. These needs can be related with the daily life or their cognitive being.

The preferred development approach used for several ambient assisted living projects is the user centered design approach rather than technology based or problem focused approaches. In particular, user centered design means that the design and development processes involve elderly users and their requirements at all stages of the project. Hence, the customization of user interface according to elderly preferences would become more acceptable. During the development processes designers come up with different graphical user interface prototypes and at each iterative stage they customize their prototype according to user feedbacks.

In this chapter, we explain different aspects of graphical user interface specifications such as colors, menu design and the size of buttons. We focus on their functionalities and the design considerations under the light of experiments carried out for investigating the elderly impairments. Additionally, we focus on their outcomes of application evaluations.

3.1. Color and Contrast

While the age increases, several physical changes gradually occur in eyes such as yellowing of the eye lens. However, the effects of those impairments become noticeable

after forties [36]. These visual handicaps of elderly people imply several vision considerations or restrictions to user interface designers.

The papers [29, 30, 37] show that elderly people mostly have reduced visual sensitivity to colors ranged between blue and green. The decline in the lack of registering capability of violet light of eyes results in difficulty for the elderly people to distinguish blue, green and violet. It is easier for the elderly with less visual sensitivity to see red-yellow tones. Color restriction should not be underestimated because it is a significant parameter for designers since the user interface will be an every day-use-application for the older people. The user will interact visually with the user interface at all stages. Hence user interface designers should consider this color restriction during their design processes.

Although the color restriction is an important design issue, it is not considered in some of the projects [38, 39], rather the designers focus on the distinctive user needs. For example, COGKNOW project [40] which is a pervasive healthcare project specialized for elderly people suffering from mild dementia aims to develop a cognitive device combined with current smart home technology to provide a suite of services driven through a user centered design process. However the designers of the project prefer to use blue tones for their user interface (Figure 3.1 and Figure 3.2) which may not be acceptable for older people who have difficulty to see blue-green ranged colors. This may result in declining usability and hence acceptance of the system. Since no experimental evaluation about the color choice is carried with elderly, the acceptance of the system is not reported in this project.



Figure 3.1. COGKNOW Homepage [40].



Figure 3.2. COGKNOW Reminder Display [40].



Figure 3.3. MPOWER Homepage [31].

MPOWER [31] (Middleware Platform for eMPOWERing cognitive disabled and elderly) project which aims to develop a middleware platform that enables rapid development of innovative smart house systems by using service oriented architectures such as web services, .NET, J2EE is another example for improper color choice. The Norwegian proof of concept application (POCA) of MPOWER project also uses blue for its web based user interface (Figure 3.3) but no experiments for color choice have been conducted.

Also some other designs such as SOPRANO [6], HERMES [33] and HEPHAISTOS [32] do not consider the color choice as a design parameter.

Although existing approaches do not consider the color as an important parameter, according to the researchers who carried experiments about the elderly impairments and

human-computer interaction (HCI) designs relation, color choice is a significant parameter for the acceptability of the application. Designs need to help older people to find items easily and to keep their attention focused [29]. Color and contrast have a significant role for achieving this goal. Corneal flattening of elderly reduces the amount of light that passes into the eyes which requires increase in information (text)/background contrast [30]. Hence choosing blue for background and white for information does not construct enough contrast for elderly. Blue, itself, may be an improper choice of color for elderly interface design. We enquired this issue by interviewing our experiment subjects during the interviews (Section 5.6.1.2).

3.2. Interface Elements, Fonts and Interaction Types

From the acceptance point of view, one of the significant design considerations is the size of interface elements such as buttons, links, pictures and fonts. Declined vision of elderly people puts importance on presenting the necessary information in a larger size. A normal decline in elderly vision implies empirically that at least 12 to 14 font size for text and 180 X 22 pixels for a graphic button will be acceptable by older people [6, 30].

Furthermore, since most of the elderly people's lens elasticity is reduced, they have difficulty for focusing on an item or text and forcing themselves for focusing causes their eyes to be tired. Experiments revealed that using different font styles in a text, using all capital or emboldened letters or narrow and decorative fonts result in significant-level eyestrain because it disables eyes to rest sufficiently. Designers should avoid using very bright colors since they cause after-images and tire the eye [29, 30, 41].

Visual field reduction can be cited as another impairment of elderly. This means that there occurs a contraction in the peripheral area that an elderly can see. This implies that the peripheral visual signal or stimulant should be stronger or closer to the center of the visual field in order for elderly to detect those visual signals [42]. This restriction requires that the important information should be displayed close to the center of the screen.

Most of the designs consider the restrictions about the size of interface, fonts and orientation of text for elderly during their project development processes. For example, COGKNOW project design has large buttons on the screen (Figure 3.2) in order to enable easy elderly interaction. In addition, Norwegian POCA [31] not only uses large interface elements but also displays the relevant information on a center frame of the screen (Figure 3.3).

Interaction with graphical user interfaces is held by different metaphors which depend on the main device used for user interface. These metaphors can be a clicking on a mouse or touching if a computer or a touchscreen is used, and using remote control, if a TV is used. In addition, when a touchscreen is used, drag and drop style can also be used. These different interaction types are experimented by different project groups such as SOPRANO and HERMES. Designers of the SOPRANO project came up with a result that shows that touching on a screen gives a real-life feeling to elderly and on the other hand using remote control with TV is a well-known activity by elderly people. However, since TV may not be on all the day and touching is a real life metaphor, touchscreen is preferred for our work. In addition, there are significant number of studies which investigate that the touchscreen performance for elderly usage for interacting with computerized systems is favorable [43–46].

HERMES project developers carried out several experiments in different European countries and results revealed that users struggle with dragging the finger over or holding it on the screen. Most of the time users were not thinking of continuously pressing the finger on the screen, but only tapped the element for a short period of time [31]. This problem arises because of the motor impairments of elderly. Since their joints and arthritis are stiffened and there is a high possibility of hand trembling, “drag and drop” activities are extremely difficult for some older people [30, 47]. Hence, touchscreen device is usable for touching activities, but not for activities which strain the psychomotor abilities of elderly, such as dragging. However, in general, because of its adaptability to various types of applications and the real-sense feeling, the touchscreen has become a favorite medium for human computer interaction [48]. Furthermore, Andrew Sears compared touchscreen and mouse interaction skills by comparing the performance speed, error rates, and user preference [49]. The finding was that the touchscreens yielded certain advantages in selecting targets as small as four pixels wide [49, 50].

Another outcome of HERMES experiments is that users have difficulty in keeping a user interface at their line of vision if the interface elements are scattered at screen because they hide those elements with their own hands or arms. Hence, the buttons, which are the main interaction elements, should be properly oriented on the screen in order not to cause vision problems and at the same time they should also be at a visible size for the elderly. Slower response time on complex motor tasks and reduced ability for repetitive fast movement causes problems for dragging, rotating, holding each of which is used for interacting with HERMES user interface.

Moreover, users are confused about the button element; that is to say, they do not know which element is clickable (or touchable). In addition, they also mostly do not recognize text areas to be input areas, as we have observed during our experiments with elderly. We will detail this issue in Section 7.2.

3.3. Reminder Design

Reminders appear to be a significantly usable functionality of smart home applications. Since reminder design affects directly the usability of overall design, several projects spent much effort on this issue. How much information should be displayed on alert boxes and how to display the alert box itself are important issues from the unobtrusiveness point of view. Those issues involve the device used. If, for example, TV is used then displaying an alert box gets complicated. Experiments showed that, displaying a reminder as a subtitle on TV would be unrecognizable. On the other hand, displaying it at the screen would irritate the user since he would not want to be interrupted during watching of his favorite program. Consequently, the experiment results of the project SOPRANO [21] revealed that reminders should be displayed as a subtitle first (Figure 3.4) and if it is not recognized after a while it is displayed as a full screen reminder (Figure 3.5). Nevertheless, SOPRANO designers do not focus on the design of the alert box itself and whether its color, contrast, letter stile and font, orientation would contribute to acceptability.



Figure 3.4. SOPRANO full screen reminder [51].

3.4. Interactive Sentences

SOPRANO team also dealt with the interactive sentences which are used on the buttons in order to make the user accept, confirm or chose a situation. One can use some descriptive expressions, even full sentences on those confirmation or choice buttons, whereas some very short expressions, even words can be used. We call the buttons on which there exists those short and non-descriptive expressions "OK-like buttons".

SOPRANO team's experiments implied that using "OK-like" buttons make elderly user confused about what it will mean to push "accept, OK, YES or NO" buttons. For example, if the reminder is something like "the oven remained open" and it has just OK button, then pressing OK may mean that "OK it is not a problem" or "OK I will take care



Figure 3.5. SOPRANO reminder as subtitle [51].

of it". Consequently, the user may get confused about pressing OK or not. Hence it is proposed to use interactive sentences like "I took care of it", "I have done it" [21].

In the literature, most of the designs do not consider the effect of interactive sentences. However, an acceptable interaction with the user interface by elderly is strongly related with those sentences because an elderly will not accept any application to use if he does not understand what the system tells him.

3.5. Menu Design

With menu design, we mean the design of menu structures and the functionalities that are covered by the application. Although there may be several different menu designs depending on the goal of each application, there are also some common features since the basic theme is elderly-care. For instance, almost all projects have a reminder system design. Although it is designed in order to remind elderly or caregivers of some significant events, differences may appear in the way that the alert box is displayed or the events which are covered to be monitored. That is, even the same functionalities may differ in some way from one design to the other according to the project considerations.

HERMES [33] graphical user interface prototype has a binary selection for past and future activities on the main screen (Figures 3.6 - 8). Thus, user interface is divided into two interfaces, namely, myFuture and myPast. It seems to achieve screen simplicity for main page but after the first selection, the user needs to handle performing several steps. Furthermore, HERMES interface has also a filtering feature which is used for searching an event by limiting time interval, emotions, location, person or keywords which can be perceived as complex by elderly users.

With myFuture interface, user can achieve some functions such as making new appointments, browsing events or moving an entry to another day. For those goals, drag and drop metaphor is used. The myPast interface involves user past daily activities such as retrieving audio and video of events that happened in the past.



Figure 3.6. HERMES myPast (2008) [33].

For another example, HEPHAISTOS [52] (Home Environment Private Help AssISTant fOr elderly and diSabled) which is a European TIDE research programme project provides elderly user an easy-to-use graphical user interface that helps him to control home electronic products in a wide range and handle emergency. Main screen of HEPHAISTOS shows the states of rooms that are being monitored (Figure 3.9). During the experiments, they found that the shallow menus appeared to be more perceptible than deep menu hierarchies. Since they come up with the finding that direct access to often used functions improves the acceptance, putting several direct accesses to needed functions on the main screen causes complexity which make elderly cognitively overloaded. This issue will be discussed in Section 3.6.

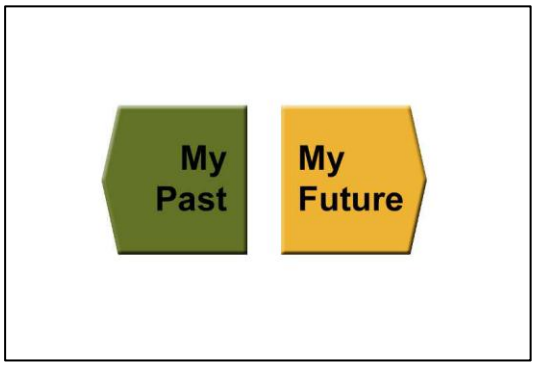


Figure 3.7. HERMES main page (2008) [33].



Figure 3.8. HERMES myPast (2011) [33].

During the development processes, SOPRANO designers came up with different graphical user interface prototypes and at each iterative stage they customized their prototype according to user feedbacks. Since they use TV as the main device, their results revealed that using numbers and arrows rather than icons for navigation purpose is more acceptable by elderly people [21]. Hence they introduce a main menu with the number-concept as in Figure 3.10. This number concept is a result of the idea that elderly people spent their time mostly in front of TV. So, they think that using the remote control for navigation will be more acceptable.



Figure 3.9. HEPHAISTOS main page [32].



Figure 3.10. SOPRANO Homepage [21].

The core scientific and technical work of COGKNOW aims to develop a cognitive device combined with the current smart home technology to provide a suite of services driven through user-centered design. The end goal is to achieve patient empowerment, greater autonomy, and to enhance the quality of life for ageing people with mild dementia [39]. Since they mostly focus on the requirements of older people with dementia, their basic area of interest is to address cognitive impairments of the users, namely to help them to remember certain actions in their daily life. In addition to cognitive assistance, the researchers cite that their aim is to address three more issues:

- Socialization
- Supporting activities of pleasure
- Safety

These three basic topics are close to our area of interest. However, on their user interface (Figure 3.1), there are direct accesses for phone, finding items, music and radio usage which may not comprehend concrete user needs. Instead, reminders for some daily activities such as eating, personal device usage and monitoring home device situation are the basic features of COGKNOW´s user interface (Figure 3.2).

The web-based design, Norwegian POCA (Figure 3.3), has six basic features including user calendar for personal activities and reminder system, contact list, medicine which provide the medicine user receives, messages for enabling messaging between user and caregivers and news for accessing local news which is a recipe for solitude and finally daily activities.

From the functionality point of view, this application is the closest to our application which we will explain in detail in Chapter 4. On the other hand, there are some differences in design considerations. For the functionality issue, our design plan has also six basic features including daily activity, medical activity, messaging, calendar, phone and video-calling. However, there are also some differences. For example, our plan for messaging is more comprehensive. On one hand, Norwegian POCA messaging feature is for only messaging with the caregiver where the user can only read and delete the messages sent by the caregiver; on the other hand, our plan is not only to enable our users to send message to their doctor but also to enable them to communicate with other system users. Furthermore, medical activity involves caregiver's remote inference if needed and medical information is displayed to user continuously on the home page or with reminders if necessary. If any unexpected situation for a medical activity occurs such that the user forgot to take his medicine, the caregiver is informed.

3.6. Two Ways of Presenting an Interface

Since the stakeholders of an elderly-care project are the elderly people and experiments show various impairments among them and they are mostly inexperienced in using technological devices, the simplicity of the application is one of the most significant parameters for acceptance.

First of all, we define the complexity of a page as the number of interface elements (Section 3.2) on that page and the page hierarchy as the number of pages that the user interact in order to complete a task. A designer can provide simplicity in two ways. One is reducing the complexity of each page displayed at a time and the other is decreasing the number of traced pages required to complete a task. The first is related with the page complexity; on the other hand the other has to do with page hierarchy. Hence, there are two main design parameters for presenting a user interface specialized for elderly care: the page complexity and the page hierarchy. For example, a "flat" version of a graphical user interface can have an index of complexity of a page as 6 on average and just 2 pages is required in order to complete a specific task on that flat version. On the other hand, a "deep" version of the same graphical user interface can have 3 as page complexity index

and 4-hierarchy of pages for the same task. Consequently, we call a graphical user interface as flat if it has more complex pages but less page hierarchy with respect to a deep version which has less complex pages but deep page hierarchy (Figure 3.11).

Hence, there is a tradeoff between complexity and page hierarchy to complete a task on a GUI. That is to say when the page complexity is high which means that user can complete his task with even one page, the hierarchy is low, which means user will interact less, even once with the user interface in order to finish a task.

George A. Miller from Harvard University conducted some experiments about people's cognitive confusion of displayed visual information [53]. He came up with the result that people start to be cognitively overloaded when the number of displayed distinct visual information is seven. In other words, the number of objects that an average human can hold in working memory is 7 ± 2 (Miller's Law). On the other hand, a recent research has demonstrated that the correct number is probably around three or four [54].

Several cognitive impairments of elderly are related with this issue. For example, reduced working memory capacity causes elderly to strain using deep hierarchies, whereas

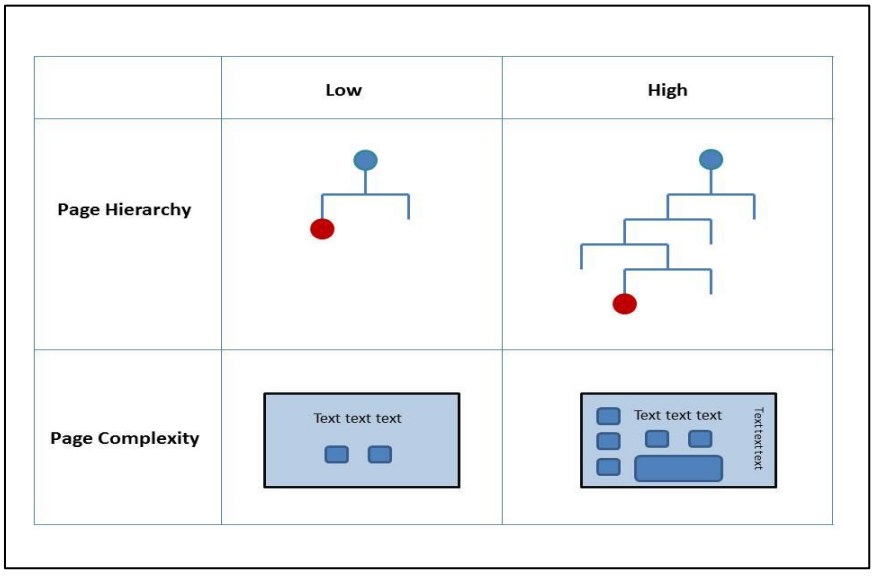


Figure 3.11. Graphical Example for Complexity versus Hierarchy.

decline in perception, spatial and visual information processing result in a significant difficulty in finding targets on a complex screen. Furthermore, when distraction information is present, the ability of elderly people to pay attention to particular details is declined.

To give a concrete example, main screen of HEPHAISTOS shows the states of rooms that are being monitored (Figure 3.9). During their experiments, they found that the shallow menus appeared to be more perceptible than deep menu hierarchies. Since they come up with the finding that direct access to often used functions improves the acceptance, putting several direct accesses to needed functions on the main screen causes complexity which make elderly cognitively overloaded.

In addition, HERMES project [33] also consider the task hierarchy and provide binary selection at the top. Nevertheless, after the first selection, although the hierarchy continues, the pages also get complex.

3.7. Conclusion

There is a significant number of applications which are developed for enabling active aging in user-preferred environments [5–9]. Since smart home technologies developed for elderly people strictly involve elderly preferences and their impairments, almost all designers prefer user-centered design. For instance, in addition to the fact that the older people have visual, cognitive, hearing or psychomotor impairments which lead to designers considering definite restrictions of elderly, they also have mostly significantly less computer or technological experience which is another important design consideration.

In general, the solutions for acceptable user interfaces for elderly people in the context of in-home pervasive health care focus on three main assistive tools. One is for memory, related with the cognitive being of elderly. The second is maintaining social contact for overcoming their solitude. Finally, the third is performing daily life activities.

In this chapter, we explained various design considerations for a GUI of ambient assisted living environment applications from the functionality and design point of view.

Studies have significant outcomes obtained from the experiments and questionnaires carried out in different countries and with several elderly people such as the research on elderly impairment, imply that the color of a user interface should be in red-yellow tones and in addition, the contrast of information-background has to be maximized. Because of this we choose to use red for our main background color and hence, in order to establish a maximum contrast between background and text, we choose white as the text color in our GUI design for elderly.

On the other hand, although some common design issues such as page orientation, color and contrast or interactive sentences can be addressed relying on the related work and experiments, after our literature survey, we found that the cognitive impairments of elderly have to do with many issues such as the task hierarchy, complexity and the trade-off between them. Consequently, we design two prototypes of our application considering this relation between the task hierarchy and the complexity.

In the application chapter (Chapter 4), we describe the main philosophy of our two application prototypes, how they differ from each other and, mainly, what each application does.

4. GUI APPLICATION: FLAT AND DEEP VERSIONS AND FUNCTIONALITIES

Ambient assisted living technologies such as in-home healthcare systems strongly involve the end users during their development and design processes in order to meet the requirements and hence the acceptance of elderly people. We followed user centered design for our application. We consider the trade-off between the task hierarchy and complexity as our basis of interest during the experiments (Section 4.1) and come up with two prototypes of user interface which are flat and deep versions. Basically, our graphical user interface, as the interaction unit of the smart home designed for elderly care, assists elderly people to help them to live independently. Particularly, it assists their cognitive impairments with handling the information flow in the case of emergency, with a reminder system for reminding them their routines and it provides them social contact such as messaging and phone conversation. In this chapter, we explain the design of our application, the underlying design considerations and the main functionalities.

As a result of our literature survey, we come up with some design specifications involving visual, hearing and motor obstacles. For example, we choose red as our main color of design because of the fact that elderly people mostly have reduced visual sensitivity to colors ranged between blue and green [29, 30]. We choose our interactive sentences, which is also involving cognitive being of the user, to be more perceptible rather than “OK-like” buttons. As the text color, we choose white to construct a better contrast with the red page color. We avoid drag-and-drop interaction skill since the motor impairments of elderly will cause a difficulty for such interaction skills. Furthermore, we consider the size specifications for buttons and text for elderly people for our interface elements.

In addition, cognitive impairments and hence the solutions for them may have a wide range of research. Understanding the phenomena of interacting with a device, keeping attention on any particular displayed information, avoiding cognitive overload, ability of finishing a task, learning new things, finding a target or reasoning each of which

is related to elderly cognition are some of the challenging issues of providing the simplicity and so the acceptance for older people.

Interaction with the application designed for homecare systems basically means that we expect the elderly user to complete some tasks via the user interface such as adding a reminder, sending a message to his friends/caregiver or using some medical devices for measurements. These tasks are strongly related to their cognitive capacity. The papers [55] and [56] show that the reduced working memory capacity results in poor performance in completing a wide variety of those tasks.

Hence the overall design philosophy needs to rely on the aim of completing a task without any cognitive overload. Consequently, sequence of interactions required in order to complete a task is the important parameter of that philosophy while complexity per page is another important parameter for the acceptance of the system.

4.1. Complexity and Page Hierarchy

In this thesis, we focus on this dichotomy of two ways of presenting a user interface. We study the effect of the tradeoff between the page complexity and the page hierarchy of a user interface to the acceptance of elderly end users in the context of in-home pervasive healthcare environment.

Relying on the literature [56, 57] and considering the decline in elderly cognitive capacity, if a task does not require any external device, we define a deep interface as that the tasks addressed by more than four steps of interaction with that graphical user interface. In contrast, a flat interface means that the user can achieve his goal at most four steps of interaction. For instance, on a user interface version if setting a reminder requires four steps, then this interface is said to be a flat interface. On the other hand, if an external device is used, each step of interaction with that device adds up to the interaction sequence.

While defining the complexity as the density of the user interface elements such as buttons, links, pictures or text on an individual page, we consider not only the touchable or clickable elements as the elements that add up to the complexity of a page but also the non-

interactive ones, such as tables and texts because decline in elderly's perception, spatial and visual information lead to difficulty in focusing on a target. In addition, in the presence of distracting information they cannot pay attention to particular details [29, 30]. According to the Farrington's study [54], one page can have high complexity with more than four interaction elements on it; on the other hand it can be called a non-complex page with less than four interaction elements on it.

Consequently, we provide our users two different user interfaces: one is the flat version and the other is the deep version of our application. In Table 1, the complexity and the hierarchy indices are shown. For calculating the complexity index of a version, first, the average of interface elements on the pages required for each task is taken. Then, the average of these numbers corresponding to three different tasks is taken to reach the complexity index of the version. For calculating the hierarchy index of a version, the number of interface elements on each page is replaced with the number of pages required in order to complete a task. Calculations are given in Appendix D.

Table 4.1. Page Complexity and Page Hierarchy Indices of Two Versions.

	Flat Version	Deep Version
Complexity Index (C)	4.14	2.78
Hierarchy Index (H)	3.33	6.0

4.2. Functionalities of the Application

Our application has four main functionalities: Agenda, Messages, Video calling and Medical. On the homepage, our application has the navigation buttons for these functionalities at two sides (Figure 4.1). We put these buttons at the sides in order to decrease the sight loses caused by the user hands or arms during the interaction. In addition, some information about the day, weather and time is displayed on the homepage. The basic version is used during experiments but we also have an enhanced version with richer functionalities. In our enhanced version (Chapter 6), we also display the upcoming

reminders, social activities, medical information from pulse-oximeter measurements and visual information about arrived messages on the homepage.



Figure 4.1. Home Page of our Application.

4.2.1. Agenda

Agenda functionality enables a user to set a reminder for his important activities or for some routines. If the user does not respond to a particular reminder for a while, the system informs his relatives or caregivers. On the flat version, the user can input all reminder information such as date, time and subject on one page and complete the task by tracing three pages (Figure 4.2). On the other hand, on deep version, the user needs to trace seven pages in order to set a reminder. On each page, different information about the reminder is asked to the user (Figure 4.3). A sequence diagram for adding a reminder to the agenda on both the flat and the deep version is shown in Figure 4.8.



Figure 4.2. A screen from Agenda functionality (Flat version).



Figure 4.3. A screen from Agenda functionality (Deep version).

4.2.2. Messaging

Messaging functionality is for addressing their solitude. The elderly users can send messages to their friends, relatives or caregivers, read and compose messages. The flat version (Figure 4.4) requires 4 pages to send a message to a friend, while the deep version requires seven pages (Figure 4.5).



Figure 4.4. A screen from Messaging functionality (Flat version).

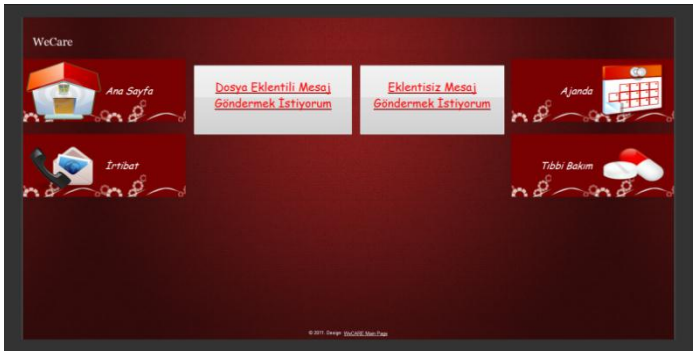


Figure 4.5. A screen from Messaging functionality (Deep version).



Figure 4.6. A screen from Video-calling functionality.

4.2.3. Video-calling

Videoconferencing is another functionality designed for elderly needs for social contact. System enables users to call their friends by just touching their picture (Figure 4.6). Messaging and video-calling functionalities are reached via the navigation button ‘Contacts’ (Irtibat in Turkish) from the homepage. For video calling purpose “Skype buttons” feature of Skype program is used. When the user touches to a person’s picture, the Skype program opens automatically and calls the relevant person directly.

4.2.4. Medical Activity

The medical activity functionality is for monitoring the daily medical activity of the elderly (Figure 4.7). On the medical activity page, user can find his weekly or monthly medical routines which are gathered as daily information at homepage.

In addition, user can measure her/his pulse rate and blood oxygen saturation using a wireless pulse-oximeter device. When s/he uses the device, system automatically recognizes the data and stores it. These four functionalities are provided by both flat and deep versions of our application.



Figure 4.7. A screen from Medical functionality.

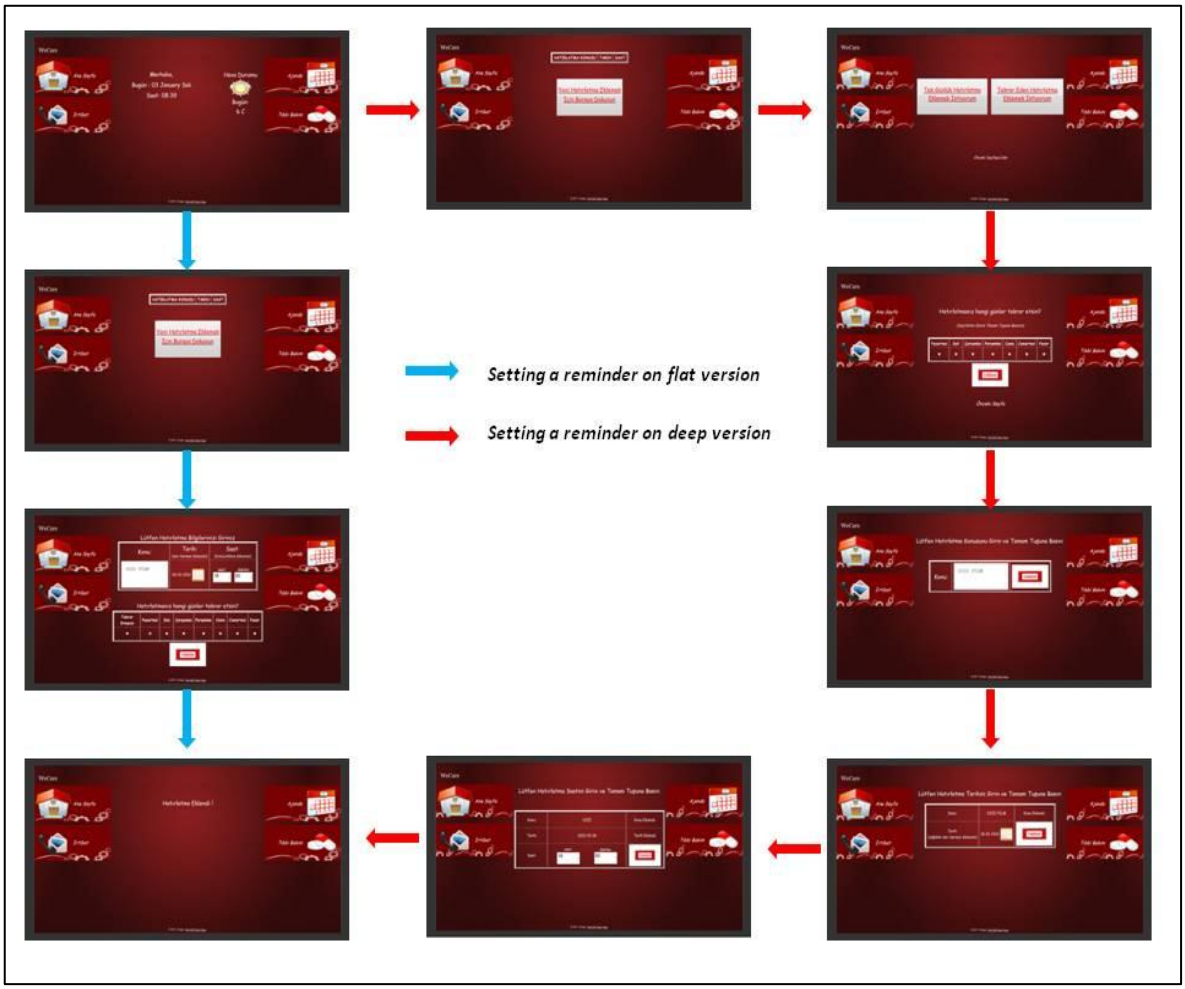


Figure 4.8. Example task sequence on flat and deep versions (setting a reminder).

4.3. Implementation

For implementation, we used three tools: PHP for graphical user interface implementation, C++ for implementing the pulse-oximeter communication with the interface and MySQL for the database purposes. We use PHP as interface development tool because of the fact that we chose our application to be web based. There are several reasons behind our choice. Firstly, no installation on client´s equipment is needed and hence it will be attainable through internet regardless of the place and the device used.

Secondly, it will have minimal hardware and software requirements which are essential for the end user in order to function on it [31]. Only choosing a main device for elderly according to his or her preferences will be enough to attain the system functionality.

Finally, having a web-based application enables the communication between different end users to be easier compared to other possible standalone applications. Moreover, addressing the emergency situations and informing the caregivers or relatives will be easier over the Internet.

In addition, we implemented the pulse-oximeter medical activity by using C++ because of its advanced and compatible libraries of Bluetooth programming. It has also the compatibility with the mysql database which we used for saving the data. Together with the reason mentioned, since both the PHP and the C++ programming languages have advanced libraries for mysql database, it was convenient for us to use PHP and C++ together for our GUI development. An example code is given in Appendix E.

To sum up, cognitive impairment is one of the most significant variables for home healthcare interface designers since the research [29, 30, 55, 56] shows that other handicaps related to vision, hearing and psychomotor can be addressed by manipulating the graphical user interface elements on the pages, but the underlying philosophy of the graphical user interface design has much to do with the cognitive impairments of elderly.

In this chapter we explained why we choose the cognitive impairments as our main concern of design. We described common design considerations of our application such as color, text size or contrast and two approaches corresponding to two ways of presenting an interface. Also we give information about the functionalities and the differences between flat and deep versions.

These two versions are experimented in order to understand the acceptance of the complexity and the depth level. In Chapter 5, we explain our design of experiments.

5. EXPERIMENT DESIGN

In this chapter, we explain the design of our experiments. We also explain how the experiments are related to the functionalities of two versions of our interface. Furthermore, the definitions of tasks that involve the functionalities of the application and our main experiment parameters are explained.

The goal of our experiments is finding the choice between the complexity and the page hierarchy for an acceptable user interface by the elderly. In other words, we carried out experiments in order to find out whether an interface with several interface elements on each page but having less hierarchy or an interface with less interface elements on each page but having deeper hierarchy would be more acceptable for elderly people who have different handicaps such as cognitive, visual or motor impairments or limited technological experience of using the in-home pervasive healthcare. For this goal we implemented flat and deep versions of our interface and experimented three different tasks on them with 18 elderly subjects.

5.1. Experiment Setting

We carried out our experiments in an elderly rest home in Etiler, Istanbul, with 18 different elderly people having different impairments. This rest home is one of the best of Turkey in terms of elderly care. It provides an active social life, comfortable living environment with single, double and triple rooms for elderly. The ages of our subjects range from 68 to 94. They also differ in computer experience. Some of them use computers even once a day but for a limited number of purposes such as playing a game and watching films, whereas some of them have never used a computer. They had different educational degrees and occupations such as a university lecturer or a housekeeper.



Figure 5.1. Touchscreen device used for experiments.

Our application interface is displayed on a 23 inch (58.4 cm) LCD and full HD touchscreen integrated computer with Windows operating system (Figure 5.1). We chose to use a touchscreen because of usability and adaptability reasons. It allows elderly to easily interact with the system [57, 58].

We used Recording User Input (RUI) program [59] for recording our subjects´ inputs during the experiments. RUI is a software tool which records the user input such as mouse clicks, key strokes, mouse movements and time for Windows and Mac operating systems. It has its own user interface for manipulating the record choices and it stores the output in a log file (Appendix C).

5.2. Requirements of Test Subjects

Since our experiment parameter involves the cognitive impairments of elderly people, the main requirement of a test subject is having a level of mild dementia. For determining the sufficient level of dementia, we contacted with health professionals. Although the level of dementia can be various among the elderly, literature survey revealed that it is the best way to choose test subjects aged between 65 and 95 for having convenient level of cognitive strain [35, 60, 61].

Most of the older people are considered to have little experience in technological devices even in the Internet. However, there are also some elderly who are accustomed to technological PDAs and Internet. Hence, we require not only a reasonable level of dementia but also not too much expertise of technology in order to set up our complexity versus hierarchy experiments.

5.3. Task Specifications

For our experiments, we wanted users to complete three different tasks each of which is related to one functionality of our application on two different user interfaces. These versions and the concepts of complexity and hierarchy are explained in Section 3.6 and Section 4.1.

The tasks we asked for test subjects are video-calling a friend, setting a reminder and sending a message to a friend. We choose this order in which subjects perform the tasks from the easiest one, which requires fewer steps of interaction, to the most difficult one. This order of tasks is the same during the experiments for all subjects in order to get interpretable feedbacks. Otherwise, if the order is different for different subjects, they may get familiar to the application in different ways and time which may result in inconsistent outcomes.

The tasks require operating the working memory, explicit memory (learning ability), processing the perception, spatial and visual information and paying attention on different interface elements, each of which is related to cognitive level of the test subjects.

In order to explain the experiments, we provide a leaflet which includes the tasks with details and some simple information explaining how to perform the tasks, for each user. This leaflet is also included in Appendix A.

5.4. Measures

We have a questionnaire and an interview, included in Appendix B, for getting the test subject's impression and feedbacks about the application and the underlying approach. Since these subjective measures are not enough to interpret the results, we also need objective measures in order to interpret and show the results experimentally. Furthermore, these measures need to express the results in consistency with the feedbacks of test subjects. For example, if a high level of a measure implies a cognitive overload about one version of the application, than the user feedback about that version should imply the same result.

Next to the questionnaires, used for obtaining subjective feedback, we developed five objective measures, based on the interaction of the subject with the interface using RUI program. As also discussed in the literature [29, 62], we choose our objective metrics to be the time for a subject to complete a task, inter-interaction time, which is the time between the user´s two subsequent interactions, the number of touches to the screen, the number of keystrokes and the number of errors, which we define in Section 5.6.3.1, until finishing the task. For instance, a long time for completing a task or a large number of errors implies a cognitive overload. On the other hand, a large number of touches resulting with success in finishing a task may imply refraining from the complexity of pages.

5.5. The Experiments

We carried out two experiments in order to come up with a reasonable result about the relation between complexity and hierarchy of a user interface designed for elderly in an in-home healthcare scenario. For this purpose, we have two basic approaches corresponding to our two experiments. One is the flat approach corresponding to Experiment 1 in which the subjects are requested to complete all three tasks on the flat version and repeat one task on the deep version and the other is the deep approach corresponding to Experiment 2 in which subjects are requested to complete all three tasks on the deep version and repeat one task on the flat version.

Now we explain the steps that we go over during the experiments:

- We provide them a leaflet (included in Appendix A) explaining the task to perform. Before providing them the written explanations, we introduce our application on the screen to give them an insight.
- The second step is performing the tasks. We want each subject to perform three tasks with the flat or the deep approach. While they perform the tasks, we record the five measures discussed in Section 5.4, with the help of the RUI program (Appendix C).
- Immediately after performing three tasks on a specific version, we ask them which of the three tasks was the most difficult for them and want them to repeat it on the other version. Namely, we ask them to repeat that task on the flat version if he tested the deep one first or the deep version if he tested the flat one first.
- Then, we provide them a questionnaire (Appendix B) to be filled. It includes the questions about their impression and feedbacks about the version they tested.
- After asking them to fill the questionnaire, we interview and ask some other subjective questions included in Appendix B.

5.6. Experiment Results

As we mentioned, for interpreting the results, we have two main categories of metrics. One category is the subjective metrics which includes the questionnaire and the interview, and the other is the objective metrics.

We first went to elderly rest home and talked with 30 elderly one by one in order to explain what we want them to do during the experiments because after some attempts, we realized that it is very difficult to gather them at the same time at a common place and explain the experiments as a group.

After an intense effort, we tested our interface designs with 18 elderly. 10 of the subjects attempted Experiment 1 and the 8 of them attempted Experiment 2.

5.6.1. Subjective Metrics

For the subjective evaluation of the interfaces, we provide them a questionnaire having 11 questions about the two versions of our interface and about three tasks they completed and an interview with 6 questions for further evaluation of the versions. Both the questionnaire and the interview are provided at Appendix B.

Although almost all elderly tend to give a more positive feedback than they performed in the tests, these subjective evaluations also give us significant sense about our design and the relation between the page complexity and the page hierarchy, which is the basic point of the experiment.

5.6.1.1. Questionnaire. The questions included in the questionnaire and the answers given by elderly are shown graphically in Figure 5.2-9. We provide the results of the questionnaire separately for the flat and the deep versions in the same chart in order to make comparative evaluation simpler. Moreover, we do not provide the charts for the multiple choice question (2^{nd} question) and the ones which are answered as to be positive by all of the subjects (7^{th} and 10^{th} questions).

As can be seen in Figure 5.2, the majority, about 56% of the subjects (Exp.1 and 2 together) did not use a computer before or just used few times in their lives. Further, about 40% of the subjects use a computer at least once a week or at least once a day. From the computer usage point of view, there is a similar distribution between the two groups of subjects which reveals that there is no dominance of a group to the other (Figure 5.2). In addition, having both computer-users and non-users provides us heterogeneity in our experiments and this makes the experiments more realistic. Considering the experiments 1 and 2 together, 72% of the computer literate subjects use the computers for accessing the Internet, almost all their time spent in front of a computer (Figure 5.3).

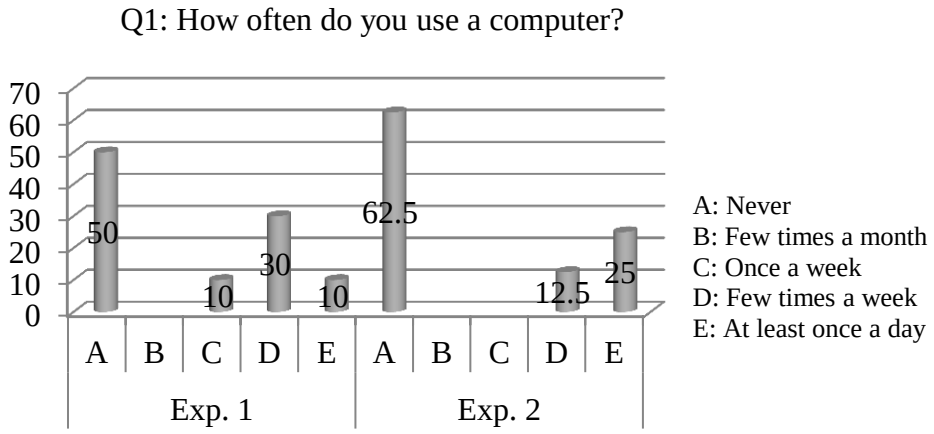


Figure 5.2. Computer usage of the subjects.

This data is also useful because the existence of computer users among the subjects provides heterogeneity in terms of familiarity to interface usage. This familiarity is higher for Internet users compared to the people who just use computers for only game or video-calling purposes. In other words, interacting with an interface via the interface elements such as buttons, links, and interactive sentences is significantly more frequent than interacting with a game or video-calling-purpose interfaces.

After the evaluation of the results presented in Figure 5.2 and 5.3, Figure 5.4 shows that the majority of the subjects (66.6% - Exp.1 and 2 together) do not feel comfortable while using a computer.

The Figure 5.5-7 shows the variation of our subjects in terms of their computer skills. Rest of the figures in this section is about the comments and the performance of the subjects.

Figure 5.5 indicates that, 70% of flat users find it easy or very easy (40% and 30% respectively) and 75% of deep version users find it easy or very easy to complete the three tasks. The ratio of flat users who think that it was difficult to complete three tasks in general is 5% higher than the deep users thinking the same. This result is consistent with the objective metric results that will be described in Section 5.5.3.

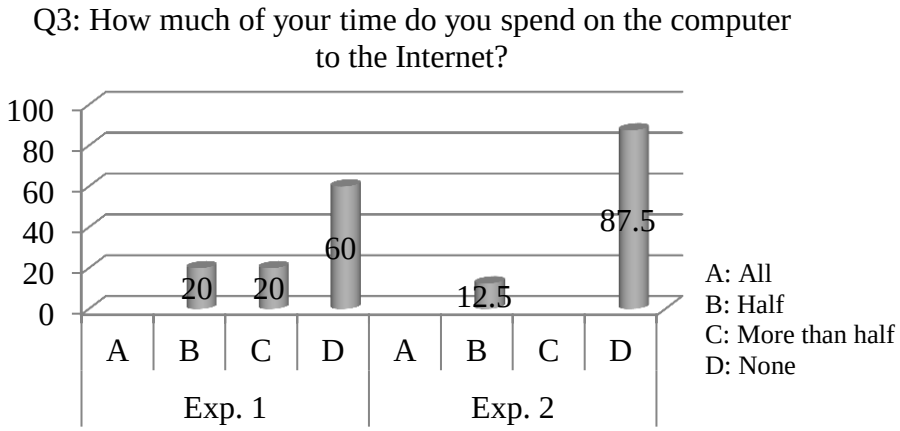


Figure 5.3. Internet usage of the subjects.

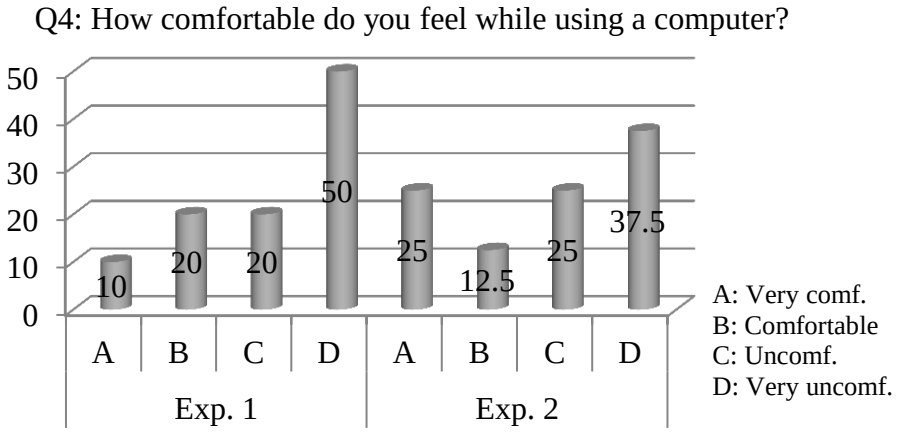


Figure 5.4. Computer usage comfort.

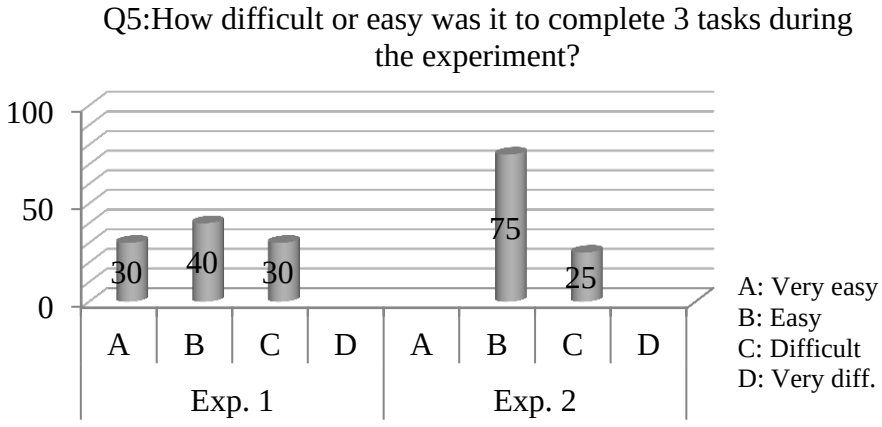


Figure 5.5. Evaluation of tasks.

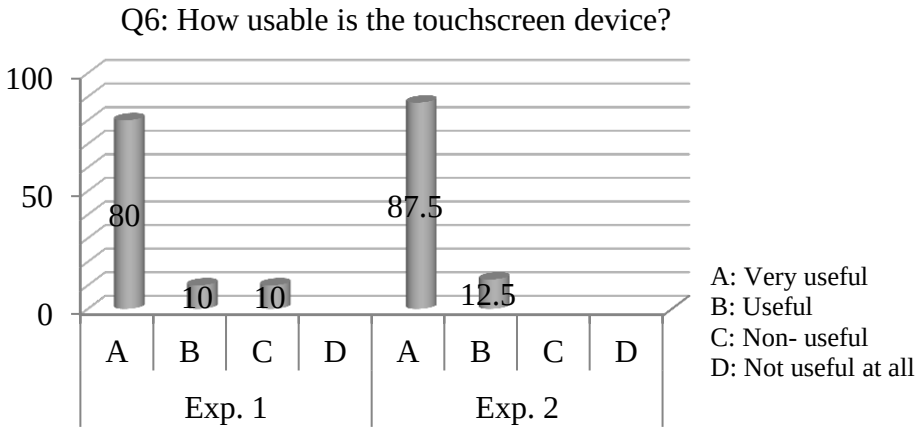


Figure 5.6. Evaluation of touchscreen.

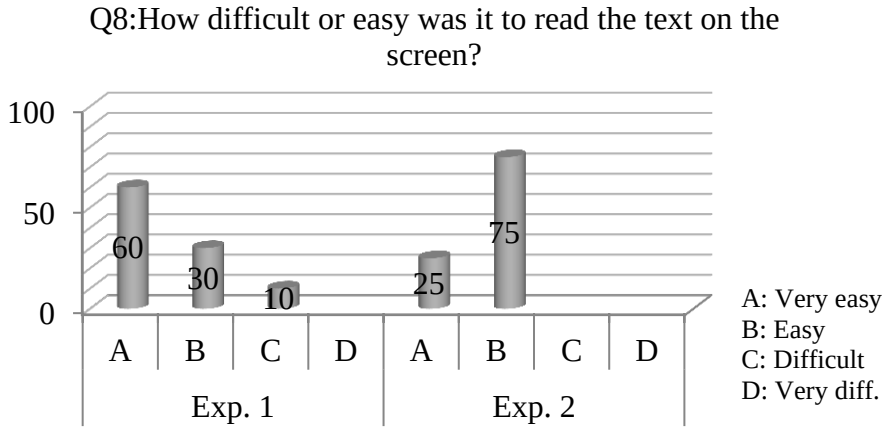


Figure 5.7. Evaluation of the text sizes.

During our experiments, considering the flat and the deep users together, 83.3% of the subjects found the touchscreen very useful and 11.1% found it useful (Figure 5.6). Only the one of our subjects found it non-useful in total (when the deep and the flat users are considered together).

After the literature survey, we chose to use 24 and 36 pixel font size for the texts displayed on the user interface (Section 3.2). Our experiments showed that this choice is convenient because the 95% of the users said that they found it easy or very easy to read the texts.

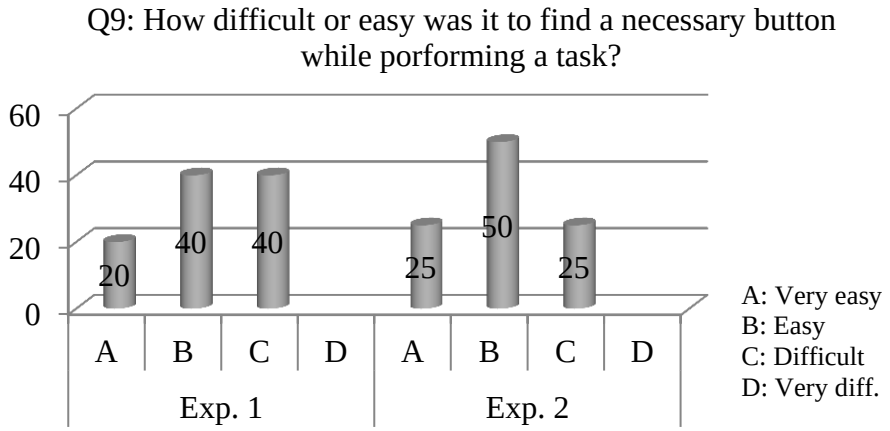


Figure 5.8. Finding the target.

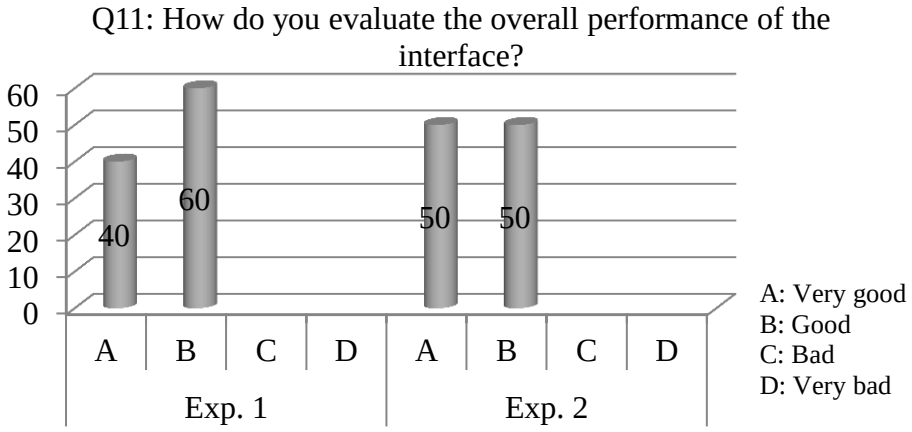


Figure 5.9. Overall performance evaluation.

Question 9 is one of the most important questions in the questionnaire (Figure 5.8) because it is directly related to the dichotomy between the page hierarchy and the page complexity. 25% of the deep version users (Exp. 2) said that it was difficult to find a necessary button or any interface elements during completing a task. This ratio is significantly high for flat users (40%), which is reasonable because the flat version interface has more interface elements on an individual page than the deep version. This strains the reduced working memory capacity of the elderly to concentrate on a target and find the target on the interface [30].

The last question was about the subjects´ evaluation of the overall performance of the application (Figure 5.9). None of the users found the performance of the application “bad”

or “very bad”. 40% and 50% of the users evaluated the application as very good in Experiment 1 and 2, respectively. They also said that the application is just good with the percentage of 60% and 50% in the Experiment 1 and 2, respectively.

Besides the biasing feature of any questionnaire, the elderly also have a tendency to evaluate the experiment outcomes positively even if they did not like it or they had difficulty during any task. Some of them might consider the questionnaire as the evaluation of their own performance. So, this tendency also increases the ratio of the bias in the questionnaire. Consequently, we used the objective metrics in order to normalize the possible bias (Section 5.5.3).

5.6.1.2. Interview. After testing the application and providing the subjects with the questionnaire, an evaluation interview was conducted, in which the experiences of the subjects and their further thoughts concerning the usability and the perception about the application were discussed. The interviews were semi-structured and included the same questions for both flat and deep version users.

According to interviews, 61.1% of all subjects, regardless of the version that they used, said that they prefer to use touchscreen rather than keyboard-mouse combination. 27.8% preferred classical keyboard and did not like the touchscreen, mostly because of the difficulty of text inputting. In other words, most of the subjects who did not like touching, cited that the problem was only with the touch-keyboard, not with the touching to buttons or other interface elements.

During experiments, we wanted our subjects to repeat the task that they found to be most difficult on the other version that they did not use. After these tries, we asked them to state in which version they completed the relevant task easier. Our aim for asking this question was to find any implication about the difference between two versions. In contrast, 50% of the flat users and 75% of the deep users found the second version, the version that they did not use for other tasks, easier. Although the difference of two percentages may imply that the flat version is chosen in general, most of subjects who prefer the second version said that this choice was because of the fact that they had become a bit more experienced by using the other version for three tasks.

When it comes to color and contrast, all subjects were pleased about the contrast and said that they can easily distinguish the text in white color on the red background. On the other hand, two subjects did not like the red background. They thought that red, itself, is too flaming and can cause to dazzle their eyes after a while.

When we asked about additional functionalities, three of them denoted that having internet option, chatting and music functionalities will be an improvement for the application. 83.3% did not specify anything as additional functionality. As a negative feedback, one subject wanted us to separate the calling and messaging functionality which can be directly reached at the home page. One subject wanted larger text fonts, three subjects thought that it was hard to attach a document to the message. A portable device was suggested and finally one suggested changing the sequence of the letters on the keyboard as like on the F-type keyboard.

Interview findings provided us a deeper insight of the evaluation and thoughts of elderly subjects. In next section, we explain our objective metrics and their implications.

5.6.2. Objective Metrics

In this section, we explain the outcomes of the objective metrics and their design implications. The records of all tasks on both versions are provided in Table 2.

5.6.2.1. Error. The committed errors during the experiments have significant implications on the performance of our two versions. First of all, we define an error as touching a wrong button (so, going to a wrong page direction), entering a wrong input (for instance, entering 18:30 instead of 18:00 for reminder time), not touching a necessary button (for example, not touching to “send” button after entering the message text) and skipping a step of the tasks defined on the leaflet provided to them.

Table 5.1. Objective Metrics Results.

		Phone		Agenda		Message		Total	
		Flat	Deep	Flat	Deep	Flat	Deep	Flat	Deep
error	Total Errors	2	6	16	16	7	15	25	37
	Average Error	0.20	0.75	1.60	2.00	0.70	0.88	2.50	4.63
	Standard Deviation (avg. error)	0.00	0.50	0.66	1.00	0.37	0.99	1.20	2.83
	Average Error(per clicks + keys)	0.029	0.086	0.047	0.065	0.024	0.068	0.036	0.069
time (sec)	Total Time:	594.6	703	2120	1910	1387.4	1354	4102	3967
	Average Time	59.5	87.9	212.0	238.8	138.7	169.3	410.2	495.9
	Standard Deviation (avg. time)	24.6	35.2	78.7	68.6	54.3	69.7	110.6	138.9
	Total Inter-touch Time	109.14	96.89	59.02	65.09	53.23	51.21	73.80	71.06
	Average Inter-touch Time	10.91	12.11	5.90	8.14	5.32	6.40	7.38	8.88
	Standard Deviation (inter-touch time)	5.11	3.53	1.40	1.49	3.08	2.21	2.90	1.93
clicks and keys	Total Clicks:	70	70	266	204	169	151	505	425
	Average Clicks	7	8.75	26.6	25.5	16.9	18.875	50.5	53.125
	Standard Deviation (clicks)	3.32	3.53	9.16	6.14	4.11	6.21	10.90	10.98
	Total Keys:	0	0	72	42	124	69	196	111
	Average Keys	0	0	7.2	5.25	12.4	8.625	19.6	13.875
	Standard Deviation (key)	N	N	2.71	2.22	6.55	4.30	6.07	6.49
	Total Clicks+Keys	70	70	338	246	293	220	701	536
	Average Clicks+Keys	7	8.75	33.8	30.75	29.3	27.5	70.1	67

According to this definition, one flat version user committed 2.5 errors on average whereas, 4.63 errors are committed by a person using the deep version interface (Figure 5.10). When we consider Figure 5.5, 5.6 and 5.7 together, it seems that the elderly prefer the deep version according to the questionnaire outcomes. On the other hand, the average error, which is a significant parameter about elderly usage of the interfaces, implies that the deep interface strains them more than the flat version.

Moreover, the agenda task appeared to be forcing them to make more errors compared to the other two tasks for both versions as seen in Figure 5.10.

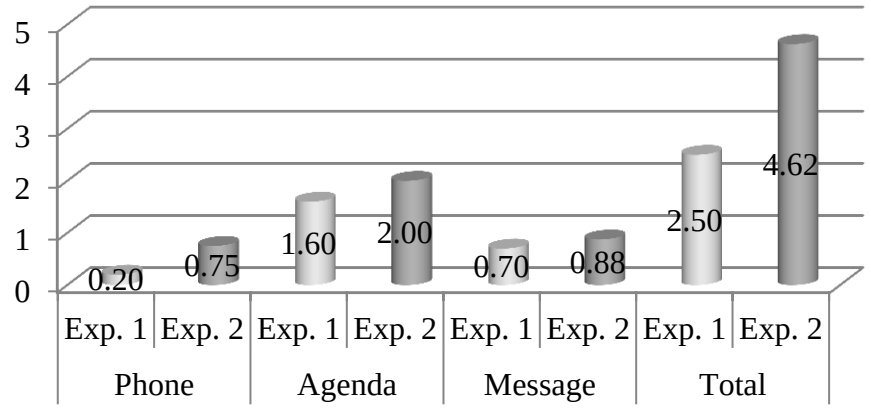


Figure 5.10. Average Error.

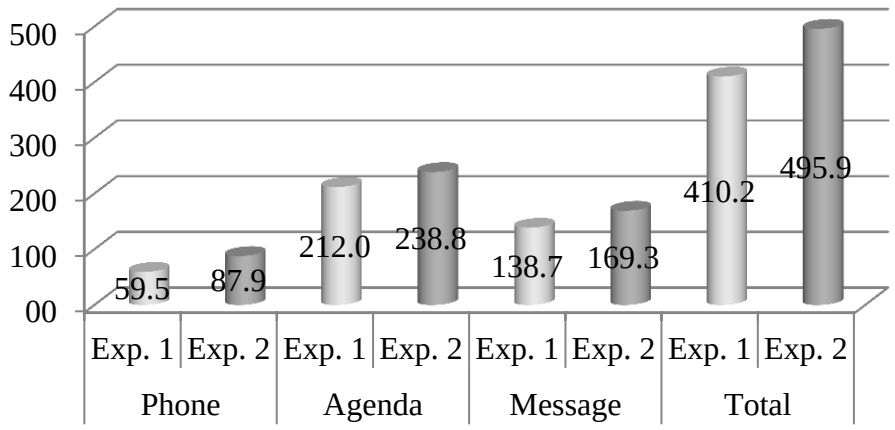


Figure 5.11. Average Time (sec).

5.6.2.2. Time. We recorded the total time and the time for each separate task. For this purpose, we pressed F1 button after each task in order to understand where the next task is starting on time line in RUI software log file. We chose to press F1 ourselves instead of wanting them to press after they completed the task because it adds extra load to their cognitive capability.

On the flat version, all tasks require approximately the same number of pages. Besides, the video-calling task requires significantly fewer pages to be traced compared to the other tasks on the deep version. However, the agenda and messaging tasks require the same number of pages to be traced.

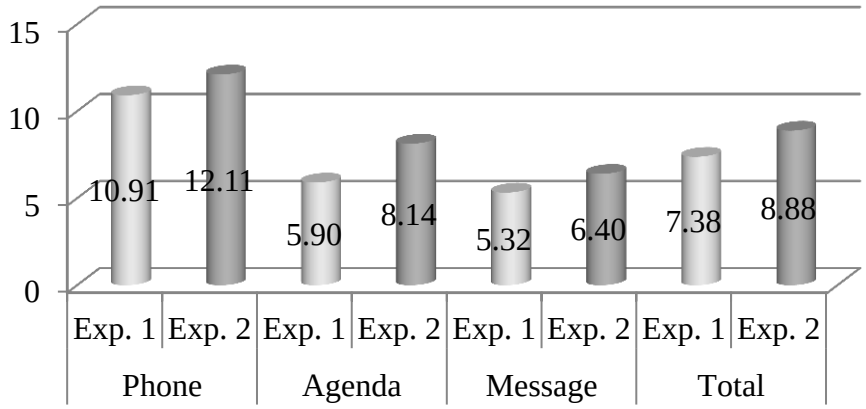


Figure 5.12. Average Inter-touch Time (sec).

In order to complete three tasks, flat users need 410.2 seconds and deep users need about 496 seconds on average. Subjects spent more time for completing the agenda task than the others (Figure 5.11). The inter-touch time, which means the time past in between to touches of the subject, is also high for the deep version (Figure 5.12). It is expected to have higher inter-touch time value for the deep version because, for each new page the user needs extra time to find which button is where (an also the other interface elements). In other words, for each page, the working memory of the user updates itself. In addition, the inter-touch time is higher for the video-calling task compared to the other two tasks. Although we mentioned about some metaphors and introduced the interface before the experiments, they tend to think more in between two touches during the first task since the video-calling task is the starting task of the experiment. The time between two touches decreases continuously regardless of the task which means that the subjects get familiar when they use the interface (Figure 5.12).

5.6.2.3. Clicks and Key Strokes. The nature of the three tasks needs more clicks (touches) on the deep version of the interface compared to the flat version. Since we want the same text for message and the same subject name for the reminder (agenda task) for all users, the key strokes are expected to be the same for both versions. Hence, the average number of clicks and keys is also expected to be higher for the deep version compared to the flat version. In contrast, we see that the number of clicks is not so much higher for the deep version compared to the flat and the number of key strokes is significantly higher for the

flat version. Consequently, the average number of clicks and key strokes is higher for the flat version, unexpectedly (Figure 5.13, 5.14, 5.15). When we analyze the questionnaire results and the user records, we see that 25% of the deep version users are daily computer users whereas only 10% of the flat users use a computer every day. So, the deep version users could easily find the right (target) button without many incorrect tries. In contrast, flat version users did many wrong attempts for clicking the right button. This situation is the same for the key strokes (Figure 5.14). This is why the average number of clicks and key strokes appeared to be higher for the flat version.

In addition, the average number of clicks is higher for the agenda task compared to the other two tasks on both versions. Also, the agenda task is the only one which the flat version users used more clicks than the deep version users (Figure 5.13). This may stem from the high number of interface elements on the reminder setting page. Since that page has the highest number of interface elements (9 elements at the same time) among other pages, subjects had more difficulty to find their target, resulting in several unsuccessful tries.

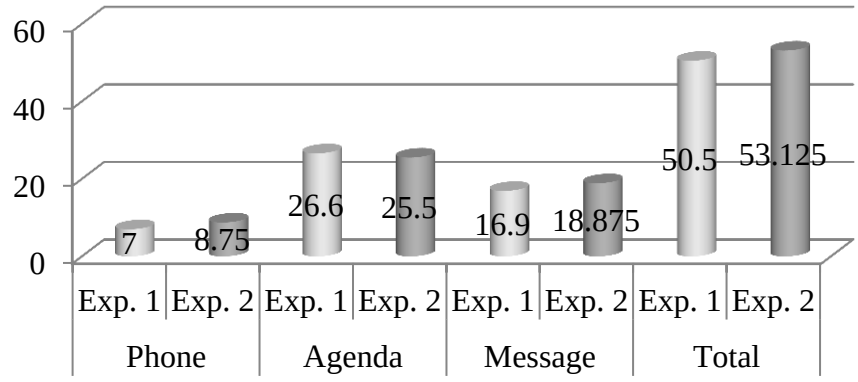


Figure 5.13. Average Clicks.

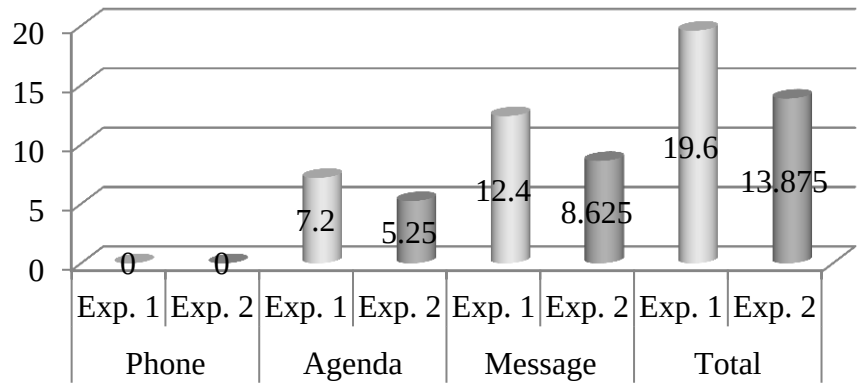


Figure 5.14. Average Keystrokes.

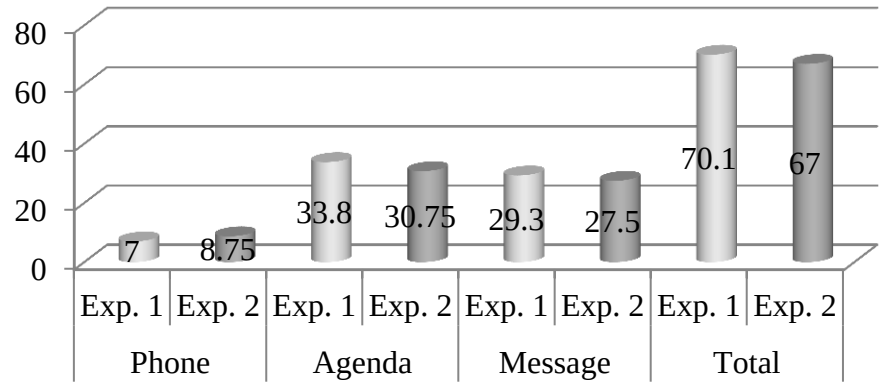


Figure 5.15. Average Clicks + Keystrokes.

5.6.2.4. ANOVA Test. In order to understand whether there is a significant difference between the data of the flat and deep version users, we chose to apply ANOVA test to our test data. We conducted ANOVA test for our five metrics, the errors, total time, inter-touch time, the number of clicks and the number of keystrokes separately.

In its simplest form ANOVA provides a statistical test that shows whether the means of several groups are all equal or not. The ANOVA test for two samples is originally the t-test. We chose to use ANOVA for testing our two samples because of the fact that we have an ANOVA calculator tool for different number of samples. In the logic of ANOVA, F-test is used for the purpose of comparison of the components of the total

deviation. The value of F used for hypothesis in ANOVA test is calculated by the formulas provided in Appendix D.

According to these formulas, we calculated F-values and created a table which shows these values for our three tasks separately for five different metrics (Table 3).

Table 5.2. F-Values of three tasks based on five metrics for both versions ($F_{(0.05, 1, 14)}$).

		Error			Total Time (sec)			Inter-touch Time (sec)			Number of Clicks			Number of Keystrokes		
		Mean	Std	F-Measure	Mean	Std	F-Measure	Mean	Std	F-Measure	Mean	Std	F-Measure	Mean	Std	F-Measure
Phone	Flat	0.25	0.43	2.00	52.64	22.85	5.64	8.98	3.10	4.27	5.68	1.93	4.23			
	Deep	0.75	0.83		87.88	35.12		12.39	3.53		8.75	3.53				
Agenda	Flat	1.38	0.48	2.22	179.88	50.74	3.80	5.40	1.01	19.26	23.25	6.82	0.42	6.25	2.17	0.73
	Deep	2.00	1.00		238.75	68.61		8.10	1.40		25.50	6.14		5.25	2.22	
Message	Flat	0.50	0.50	8.22	115.13	17.84	4.52	4.18	1.00	8.15	15.00	1.73	2.53	9.88	4.48	0.28
	Deep	1.88	1.17		169.25	69.73		5.97	1.43		18.88	6.21		8.63	4.30	
Total	Flat	2.00	0.71	6.5	372.15	85.10	4.62	6.28	1.22	10.35	47.38	9.94	1.02	17.00	3.46	1.26
	Deep	4.63	2.83		495.88	138.91		8.81	1.86		53.13	10.99		13.88	6.49	

In order to claim a significant difference between the variance of two groups, the F-measure value should be greater than 4.49 for 16 degrees of freedom [63]. Hence according to Table 4, the error, total time and the inter-touch time data indicate a significant difference between the two groups and hence, two versions of our application.

For the error metric, the phone and the agenda tasks did not reveal any significant difference according to their F-measures (2.00 and 2.22 respectively). On the other hand, for the messaging task, which requires more cognitive load, there is a significant difference with an F-measure with 8.22. Considering three tasks together for the error data, one can easily say that there is an obvious error difference between the flat and the deep versions (F-measure: 6.50). The flat version with a less error data in average appeared to be more preferable compared to the deep version (0.71 and 2. 83 respectively).

The total time reveals that, with a 4.62 F-measure data, the flat version, which has a 372.15 mean of total time, appears to be better than the deep version which has a larger mean of total time (496.88). Individually, the messaging task has an F-measure near to the significant level but not at that level, whereas, the phone task implies a significance

difference with 5.64 and nevertheless, agenda task does not reveal a significant difference for the total time required to finish each task.

The inter-touch time, which means the time in-between two subsequent touches, shows a significant difference between the two versions of our application for the agenda and the messaging tasks and a near-significance for the phone task in terms of measures of 19.26, 8.15 and 4.27 respectively. Consequently, the inter-touch time metric, in general, reveals a significant dominance of the flat version to the deep version (F-measure: 10.35).

On the other hand, the number of clicks and the number of keystrokes did not show a significant difference between the two versions for both in total and task-based data. Since the tasks require the same number of keystrokes, namely, the same input text, having an insignificant difference between the two versions is reasonable. On the other hand, although we expected that the number of clicks would be higher for the deep version which requires more interaction, the results did not show a significant difference between the two versions. But the questionnaire results explain this situation. According to the questionnaire, there is a larger percentage of daily computer users among the subjects who tried the deep version compared to the flat users. So, the incorrect attempts for clicking the target are higher for flat users (Section 5.6.2.3).

Finally, experimental results revealed that the flat version is more preferable for elderly people. Hence, a graphical user interface is to be more acceptable if it provides elderly people completing the tasks with a few pages.

5.6.2.5. Task Repetition Test. During experiments, we asked the subjects to repeat the task which they found to be most difficult. Although it becomes easy to try one task for the second time even on a different version because the subjects get accustomed to the interface, we conducted this test in order to have further insight about the difference between two versions.

The majority of the users of both versions found the messaging task as the most difficult one (80% of flat users and 87.5% of the deep users, nobody chose video-calling). According to the interview, 50% of the flat users found the second try of the task they chose to be most difficult was easier to complete, which means that for the relevant task

flat users found the deep version to be more acceptable. However, according to the metrics, their first try appears to be more acceptable compared to the second try on the deep version (Figure 5.16 – 20).

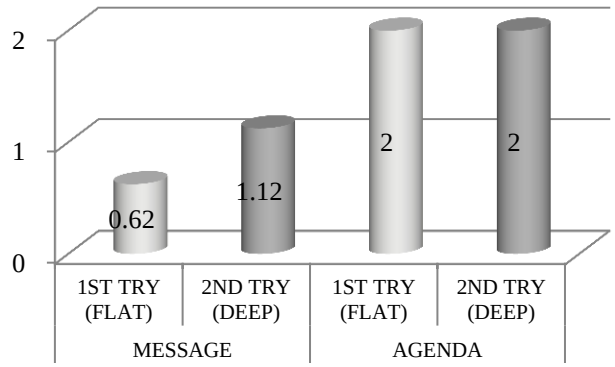


Figure 5.16. Errors for the repetition test (flat version users).

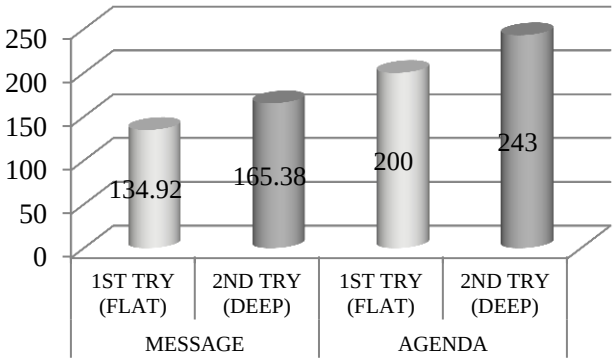


Figure 5.17. Time (sec) for the repetition test (flat version users).

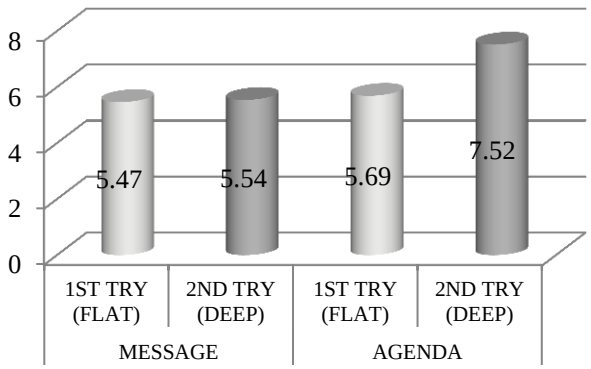


Figure 5.18. Inter-touch time (sec) for the repetition test (flat version users).

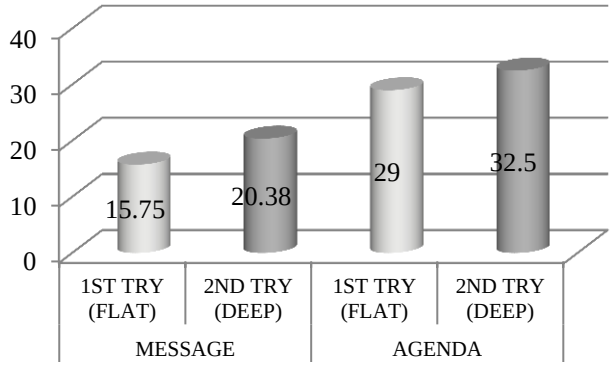


Figure 5.19. Clicks for the repetition test (flat version users).

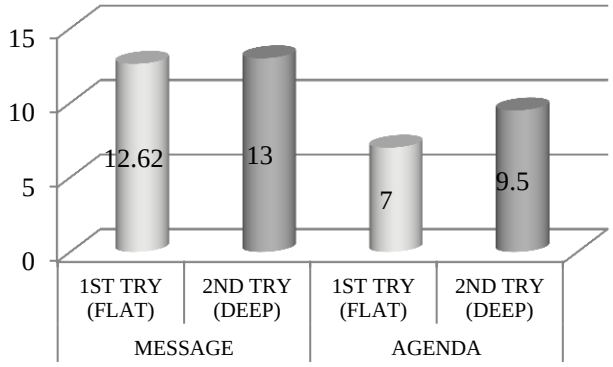


Figure 5.20. Keystrokes for the repetition test (flat version users).

As can be seen on Figure 5.16 – 20, almost all the metrics, except for the error metric for agenda task repetition (Figure 5.16), appeared to be higher for the deep version which reveals that the flat version is more acceptable for the task repetition test. The reason why the subject verbalized that the second try on the deep version was easier may be the intuition of feeling to be accustomed to trying a task for the second time.

Like the flat version users, 75% of the deep version users found the second try on the flat version to be easier compared to their first try on the deep version. This time, the interview results and the objective metrics overlap. Since only one deep user chose the agenda task to be the most difficult one, for repetition test of the deep users, the metrics based on messaging task would show more consistent results. According to the Figure 5.21 – 25, the majority of the metrics exhibit better results for the second try on the flat version

compared to the first try on the deep version. This also implies that the flat version is more acceptable than the deep version.

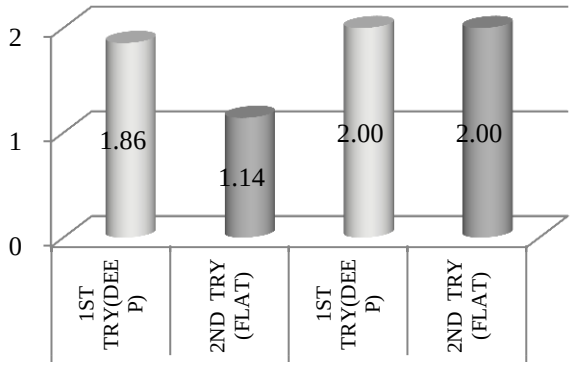


Figure 5.21. Errors for the repetition test (deep version users).

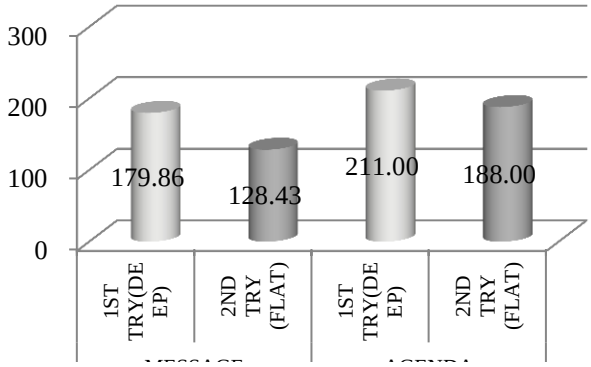


Figure 5.22. Time (sec) for the repetition test (deep version users).

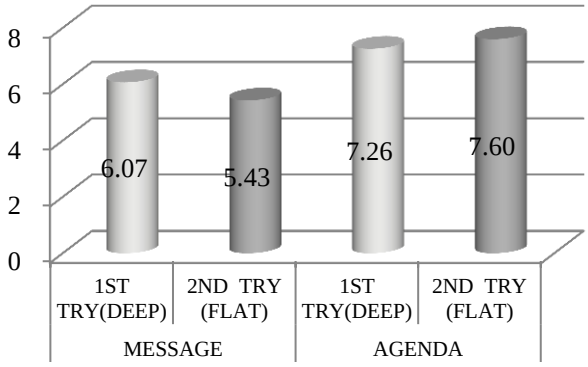


Figure 5.23. Inter-touch time (sec) for the repetition test (deep version users).

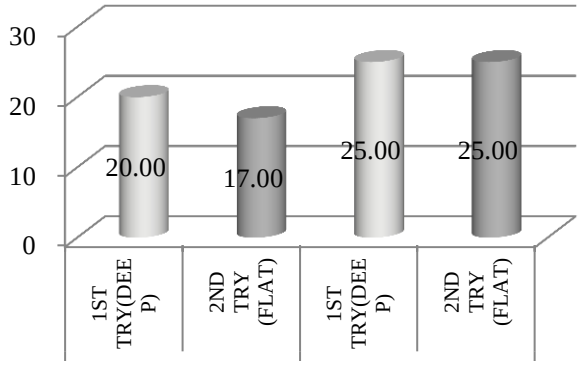


Figure 5.24. Clicks for the repetition test (deep version users).

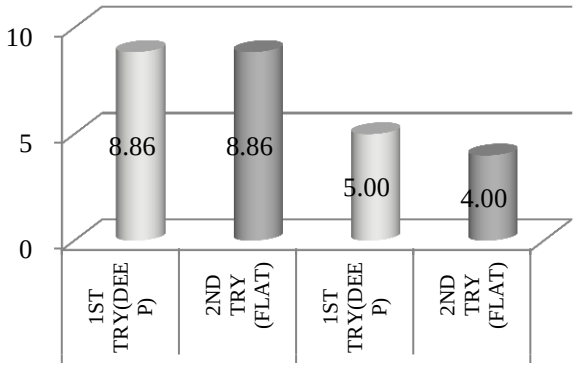


Figure 5.25. Key strokes for the repetition test (deep version users).

As a result, the task repetition experiment showed us that although the majority of the subjects report their second try to be easier intuitively, objective metrics revealed a different pattern from the interview. According to the objective metrics the flat version, which is the first try of flat users and the second try of the deep users, appeared to be more acceptable compared to the deep version.

6. ENHANCED VERSION OF OUR APPLICATION

Since the results revealed us that the flat version would be more acceptable by the elderly, we selected the flat version of the user interface as our main application and made some enhancements from the functionality point of view.

6.1. Medical Activity Enhancement

Our test version had the medical activity functionality for measuring pulse rate and blood oxygen saturation using a Bluetooth pulse-oximeter device, for monitoring the measurements of pulse-oximeter and could display this information graphically if wanted. In the case of abnormality, it informs the relevant people such as relatives or health professionals.

Although the user can get the pulse and the oxygen saturation information directly from the pulse-oximeter device, it is important to save those data for a time interval because of health monitoring reasons. Our application stores the measured data to the database for a week interval and displays it as a bar graph (Figure 6.2).



Figure 6.1. Using Pulse-oximeter.

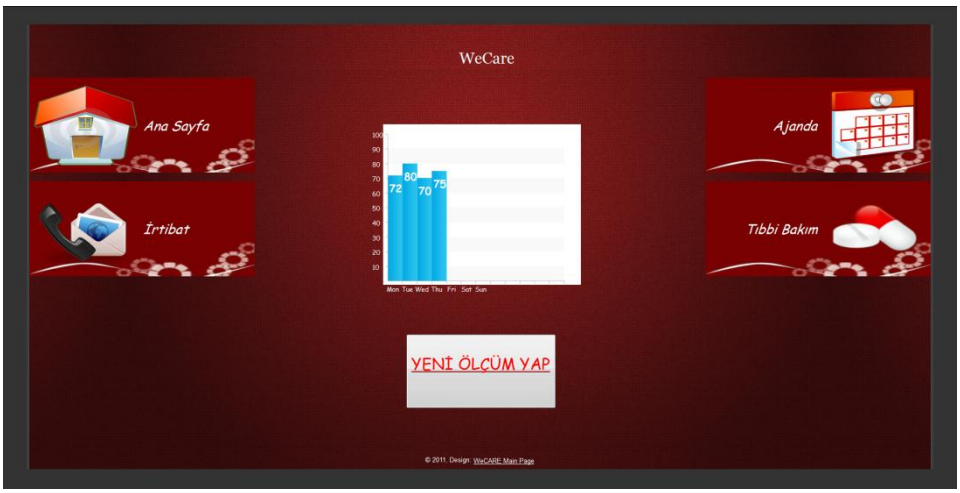


Figure 6.2. Graphical display of pulse rate results.

When the user wants to measure his or her pulse rate and blood-oxygen saturation s/he can just wear the pulse-oximeter device and touch the “OK” button on the New Measurement page (Figure 6.1). S/he can reach this page in 3 steps. The measurement automatically ends when s/he takes off the device. When the measurement ends, interface shows the last result and if the user wants to see the previous measurements s/he can go back to the Measurements page.

6.2. Reminders Enhancement

On the homepage, we have the sequence of daily activities from both the medical activity and the agenda functionalities (Figure 6.3). In addition, because of the fact that a user may not be always in front of the interface, we use audio-alerts in order to remind those activities rather than text based pop-up boxes.



Figure 6.3. Home page with visual reminders.

6.3. Homepage Information Enhancement

During experiments, some subjects suggested us to use some more visual elements for manipulating the interface. Relying on this suggestion, our enhanced version of the interface enables the user to see the photo of the person who has sent a new message on the homepage and to read the message by directly clicking on the relevant photo (Figure 6.3). This makes easier to reach the messaging functionality from homepage for reading the messages. It links the flat feature of our interface to the relatively deeper character of Message functionality.

In addition, we changed the position of daily information such as the day of the week, weather and time in order to allocate more visual field in the middle for some relatively more important information such as the just arrived messages and medicine monitoring table.

6.4. Interactive Sentences Enhancement

Additionally, we changed the interactive sentences to be further descriptive because of some confusion problems explained in Section 7.2.3. For example, we changed the sentence “Send a new message” to the sentence “In order to send a new message, touch

here” because of the fact that the elderly people remained without any action when they read such a sentence which are considered as just giving instructions. To be concrete, during experiments, elderly subjects seemed to think “yes, I should send a new message, that’s true but how?” when they read those sentences saying just “do that” and consequently they could not start to task without our help. If the users get accustomed to the interface, those interactive sentences may be shrunk back to less descriptive and shorter ones.

7. DISCUSSION

7.1. Findings

7.1.1. Contact with Elderly

A preliminary meeting with elderly subject candidates made us to realize that we will face some difficulties which we had not considered before. Firstly, during the reciprocal conversation, we had difficulties about stating our motivation. Some of the elderly considered us as salesmen; some other thought that we were teachers and went there to teach them some computer skills; some thought that we were there for a banking advertisement. As an inevitable result, we could not persuade some of them to participate in our tests because they consider the situation as a privacy invasion.

In addition, we found that it is difficult to conduct a group conversation in order to explain our aim and the experiments. It stems from two reasons. One is their hearing and cognitive impairments which prevent them to focus on the issue and make it more difficult to understand what is being explained. For example, we had difficulty to state our purpose even to two subjects at the same time. Consequently, one of them rejected to help us without stating any reason. The other reason is the difficulty of gathering them at a proper and common time. We initially asked the caregivers who helped us for organizing the meetings with the subject candidates to gather them at a common time and place. Our aim was to explain our goal to the candidates easily and in a short time. However, this did not work. Consequently, we talked to the subjects face to face; one by one.

7.1.2. Understanding the Elderly

Apart from the graphical user interface considerations in the context of in-home healthcare, understanding elderly, itself, found to be a challenging issue. Comprehending

their preferences about their own “life” will add up to the design process of a user interface specialized for them. Dr. Beverly Block, a family therapist, made a study about elderly thoughts about the life [64]. The findings of the conversation in Convalescent Home revealed that the elderly mostly want to be in control of their own lives. In the list of the findings of this study, noteworthy desires of elderly are cited such as autonomy, freedom, respect, friends and privacy. All of these findings are strongly related with the user interface design process for elderly.

In addition, during our experiments and interviews, we had the chance of understanding them deeper. First of all we can say that most of them are compassionate and lively. Although some of them hesitated to attend experiments and even touch the screen, most of them are eager to learn new things and also they are eager to meet technology.

7.2. The Interaction Metaphors

In this section, we explain some observed phenomena that give some clues about the reasoning patterns of the test subjects about using an interface. The performance results related to the metaphors such as the touching metaphor and the button metaphor are also described. On the other hand, the effect of those metaphors, the reasoning skills of elderly about some specific phenomena, is strongly related with the unfamiliarity of the elderly with a new technology or application and can easily be overcome with some definite learning activities.

7.2.1. Touching

Since most of the elderly and hence our subject group are not accustomed to using a touchscreen, they are not familiar with the phenomena of touching. Just verbalizing them that the device is touchscreen and they can manipulate it by just touching the buttons did not work. They were confused about touching and tried to press some other analog buttons

of the device or touched irrelevant parts of the screen. When we realized this situation at the beginning of the experiments, we decided to explain what touching is and how to manipulate the interface by touching. For each subject, we added this motivation to our pre-experiment annotation. This is a good example of the structural difference between a lab environment and the field; we may not probably be aware of this problem deeply in a lab environment [19].

7.2.2. Buttons

Another metaphor that the elderly strained to understand is the button phenomena. Although most of the elderly people know the traditional buttons on in-home machines or automated teller machines, they find it difficult to locate the buttons on the graphical user interface. Some of them attempted to touch the text sentences on the screen which showed us, in fact, that it was a good choice for us to combine the button and the descriptive sentences phenomena for manipulation purpose. Despite this combination, some of them strained to comprehend the button issue. Consequently we also added showing a button and how to touch it to our pre-experiment annotation.

7.2.3. Interactive Sentences

In a lab environment, after our literature survey, we found that the elderly will not comprehend the “OK-like” interactive sentences, described in Section 3.4. Instead, we choose to have more descriptive sentences such as “Add New Reminder”. However, during the experiments, we found that we need further descriptive sentences for interactive elements. For example, about 40% of the subjects (Experiment 1 and 2 in total) could not decide what to do when they read “add a new reminder”, but easily understand the other button writing “Touch here in order to attach a file” on it. Some other sentences like “I want to add a routine reminder” also caused problem for about 40% of the subjects. We think that, they consider those sentences starting with "I" as the wish of the computer itself so, when they read such a sentence, they remained with no action, awaiting an action from

the computer. Consequently, we come up with the decision that using full or full-like sentences which give direct commands about what to do such as “Touch here in order to add an attachment”.

7.2.4. Arrangement of Interface Elements

The arrangement of the interface elements is one of the metaphors that we get an unexpected outcome during experiments. The interface elements such as buttons, texts, interactive sentences and links with a changing arrangement on the screen will strain the elderly´s cognitive capability. So, a particular group of interface elements which has a specific functionality need to have a definite arrangement on the user interface. For instance, the arrangement of navigation buttons should not change for each page.



Figure 7.1. Triangular arrangement of interface elements.

On the other hand, during the experiments, we realized that not only the interface elements having the same group of functionality but also any interface elements on a specific page had better to remain in the same arrangement with the interface elements on the previous page. To be concrete, the flat version of our application has a linear arrangement of interface elements on the home page and three buttons in a triangular arrangement on one of the next pages, namely the contact page (Figure 7.1). We realized

that, after coming from the home page to the contact page, 27.8% of the subjects could not recognize the button on the top of that triangular arrangement. Hence, a static arrangement of interface elements will be more acceptable by elderly.

8. CONCLUSION AND FUTURE WORK

The rapid computerization and the aging of the world population motivate the designers to design the computerized display of the systems to the elderly people with their impairments and preferences in mind. Because of its ease of use compared to the text-based interfaces, graphical user interfaces have made it easier to display those computerized devices to the elderly people. Consequently, the customization of graphical user interfaces of those computerized systems according to the elderly preferences arises as a challenging issue.

Several impairments such as visual, hearing, psychomotor and cognitive impairments of the elderly people result in important considerations for user interface design processes. In order to provide simplicity, which is the main concern of providing acceptance of a graphical user interface by the elderly, the considerations such as color, contrast and text and button sizes, appear to be important design parameters. In other words, the acceptance of a user interface by the elderly requires the user interface to be "simple" and that simplicity requires the elderly impairments to be considered during the design processes. During our literature survey, we found several studies for addressing the visual, hearing and the psychomotor impairments, which involve the color and contrast, the size of buttons and the text and interaction types, in order to provide the simplicity. This suggested us to focus on the cognitive impairments and their implications rather than the others such as visual, hearing and psychomotor impairments for GUI design processes in order for a GUI to be acceptable by elderly people.

Our basic point was the dichotomy between the page complexity and the page hierarchy for providing simplicity. From the cognitive impairments point of view, the simplicity can be provided in two ways. One is by reducing the complexity of each displayed page and the other is by increasing the page hierarchy, i.e., the number of pages required to complete a task (Section 4.1). These two ways of displaying a user interface are inversely proportional. That is to say, for a specific task, in which the amount of user input (information) does not change, reducing the page complexity results in increasing the number of pages. Hence, there is a tradeoff between page complexity and the page

hierarchy for providing the simplicity. In this thesis, we studied this tradeoff by designing two versions of an interface. One is the flat version and the other is the deep version of user interface (Section 4.1). We tried to answer whether a flat version of a user interface or a deep version of a user interface would be more acceptable by elderly people.

For this purpose, we conducted experiments with 18 elderly people having different impairments (Chapter 5). We did two experiments: In the first experiment, we asked our 10 subjects to complete three tasks on the flat version and immediately after repeating the task which they consider as the most important on the deep version. In the second experiment, 8 subjects tried the deep version by doing the same tasks and repeat one of them which they consider as the most difficult on the flat version. During the experiments, we recorded our metrics by a program called Recording User Input (RUI). Our metrics are error, the total time, the inter-touch time, the average clicks and the average keystrokes which are called objective metrics. In addition, we conducted an interview and asked them for filling an 11-question questionnaire after the experiments and this provided the subjective metrics.

The results of both subjective and objective metrics revealed that the flat version of our interface is more acceptable compared to the deep version. We investigated that a user interface for any purpose but especially for homecare systems is required to be flat in order to be acceptable by elderly people. A user interface with pages having a complexity index around 4 and hierarchy index around 3, which can be considered as a flat interface, would not cognitively force elderly and will be acceptable.

Although the objective metrics of our first try experiments revealed that the flat version is more acceptable, the subjective metrics implied that the deep version appeared to be more acceptable (Figure 5.8, 5.10 – 12). However, the results of the second try, namely the repetition test, also revealed that the flat version is more acceptable (Figure 5.16 – 25).

Our extra findings were that the perception of elderly about the interaction metaphors such as buttons, interactive sentences, arrangements of the interface elements and even touching may be totally different compared to the people who have expertise of computer usage and technology.

For future directions, we intend to focus on some other impairments such as audial and physical impairments. Gestural interaction via the interface may provide a reasonable solution for elderly people who have advanced physical impairments. Gestural interaction can enable them to manipulate the interface by their gestures without forcing their arms, hand or fingers.

Furthermore, providing audial interaction skills for elderly may constitute a solution for people who have visual impairments and even physical impairments. Voice-manipulated interfaces would make it easy to interact with the related system for physically disabled people.

From cognitive disorders point of view, cognitive games may be added to the interface for elderly users to improve their mental being. In this way, cognitive impairments may be decreased and as a consequence, the utilization of elderly people from the home care systems and the interface may be increased.

APPENDIX A: PROVIDED LEAFLET

EXPLANATIONS

We request you to complete three tasks according to the instructions below.

TASK 1

Please make a video call to Mustafa.

TASK 2

Please, set a reminder to agenda repeating every Monday with the subject name “Film”, on date 28.10.2011 and at time 18:30.

TASK 3

Please send a message to Bilgin with an attachment of the document named “Bogazici”. Write “Hello” as message body.

(LEAFLET IN TURKISH)

AÇIKLAMALAR:

Dokunmatik ekranı kullanarak aşağıdaki 3 işlemi yapmanızı rica ediyoruz.

İŞLEM 1

Lütfen Bilgin'e "Boğaziçi" isimli dökümanı ekleyerek bir mesaj gönderin.

İpucu: Dosyayı eklemek için karşınıza çıkacak ilgili sayfada Boğaziçi" yazan dökümana 2 kez tıklamalısınız.

İŞLEM 2

Lütfen Ajandaya 10.10.2011 tarihi ve 18.30 saatine, her pazartesi tekrar eden (rutin) "Dizi Film" konulu bir hatıratma ekleyin.

İŞLEM 3

Lütfen Mustafa'ya görüntülü arama yapın.

APPENDIX B: QUESTIONNAIRE AND INTERVIEW

QUESTIONNAIRE

1. How often do you use a computer?
    a. Multiple times a month
    b. Once a week
    c. Multiple times a week
    d. At least once a day
2. For which purposes do you use the computer?

    ☐ For playing games
    ☐ For communicating with my family and friends
    ☐ For buying items online
    ☐ For performing my administration
3. How much of the time you spend on the computer do you spend for internet?
    a. Never
    b. Half of the time
    c. Most of the time
    d. I use computer only for internet
4. How comfortable do you feel while using a computer?
    a. Very comfortable
    b. A little comfortable
    c. A little uncomfortable
    d. Very uncomfortable
5. How easy was it for you to complete 3 tasks during the experiment?
    a. Very easy
    b. Easy
    c. Difficult
    d. Very difficult
6. How comfortable is the touchscreen for you?
    a. Very comfortable

   b. A little comfortable
   c. A little uncomfortable
   d. Very uncomfortable
7. Are the buttons big enough to be touchable?
   a. Big enough
   b. Too big
   c. Small
   d. To small
8. How readable are the text fonts?
   a. Very easy to read
   b. Normal
   c. Difficult to read
   d. Very difficult to read
9. How easy is it to find any button which is needed during a task, on any page?
   a. Very easy
   b. Easy
   c. Difficult
   d. Very difficult
10. What do you think about the number of interface elements on each page?
   a. There are too many interface elements
   b. There are sufficient number of interface elements
   c. There are insufficient number of interface elements
11. How do you evaluate the overall performance of the interface?
   a. Very good
   b. Good
   c. Bad
   d. Very bad

ANKET

1. Ne kadar sıklıkta bilgisayar kullanıyorsunuz?
   a. Ayda birkaç kez
   b. Haftada bir

c. Haftada birkaç kez
d. Günde en az bir kez

2. Hangi sebepler için bilgisayar kullanıyorsunuz?

- ☐ Oyun oynamak için
- ☐ Aile ve arkadaşlarımla görüşmek için
- ☐ Internet üzerinden alışveriş yapmak için
- ☐ İş ile alakalı işlerim için

3. Bilgisayardaki vaktinizin ne kadarı internette geçiyor?
   a. Hiç
   b. Yarısı
   c. Çoğu
   d. Hepsi
4. Bilgisayar kullanırken kendinizi ne kadar rahat hissedersiniz?
   a. Oldukça rahat
   b. Biraz rahat
   c. Rahatsız
   d. Çok rahatsız
5. Deneydeki 3 işlemi yapmak sizing için ne kadar kolay oldu?
   a. Çok kolay
   b. Kolay
   c. Zor
   d. Çok zor
6. Dokunmatik ekran bilgisayar sizce ne kadar kullanışlı?
   a. Çok kullanışlı
   b. Biraz kullanışlı
   c. Biraz kullanışsız
   d. Çok kullanışsız
7. Ekrandaki tuşlar dokunabilecek kadar yeterli büyüklükte mi?
   a. Yeterli büyüklükte
   b. Fazla büyük
   c. Küçük
   d. Çok küçük

8. Ekrandaki yazılar ne kadar kolaylıkta okunabiliyor?
    a. Oldukça kolay
    b. Normal
    c. Zor okunuyor
    d. Çok zor okunuyor
9. Bir işlemi yaparken sayfada gerekli herhangi bir tuşu bulmak ne kadar kolay oldu?
    a. Çok kolay
    b. Kolay
    c. Zor
    d. Çok zor
10. Herhangi bir sayfadaki tuş ve yazılar gibi şeylerin sayısı hakkında ne düşünüyorsunuz?
    a. Çok fazla sayıda
    b. Normal sayıda
    c. Yetersiz sayıda
11. Yaptığınız işlemlerle alakalı bilgisayarın genel performansını nasıl değerlendiriyorsunuz?
    a. Çok iyi
    b. Iyi
    c. Kötü
    d. Çok kötü

INTERVIEW

1. Let's think about the ATMs (automated teller machines). Which aspects of those machines do you like or dislike?
2. What do you think about the touch screen device? Is it easy to use such a device or is a mouse-keyboard combination better?
3. Is there anything that you particularly liked or disliked about that interface?
4. You repeated the task X on two different interfaces. Which one do you think is easier?
5. Is there any aspect that you liked or disliked which is common for both of the two different versions?
6. What can be added or subtracted from the interface you tried in order to make it better?

ROPÖRTAJ

1. Banka ATMlerini düşünün. Bunların hangi özelliği hoşunuza gidiyor ya da gitmiyor?
2. Dokunmatik ekran hakkında ne düşünüyorsunuz? Sizce fare-klavye daha mı kullanışlı olurdu?
3. Uygulamada özellikle beğendiğiniz ya da beğenmediğiniz bir özellik var mı?
4. X işlemini iki farklı uygulama ile yaptınız. Sizce hangisi daha kolaydı?
5. Iki uygulamada da ortak olarak beğendiğiniz veya beğenmediğiniz bir özellik oldu mu?
6. Sizce eklenmesi veya çıkarılması iyi olacak bir özellik var mı?

APPENDIX C: RECORDING USER INPUT (RUI) PROGRAM

Recording Use Input (RUI) program is an integrated and unobtrusive application that executes in the background, which can be used generically for all applications [59]. RUI software is implemented in the .Net framework with C# for Windows in order to be able to record the user input such as the keystrokes, clicks, the time and the mouse movements in xy-plane. RUI has an interface which enables the user to choose which type of action to record (Figure 49). The collected data is stored in a log file (Figure 50) which can be chosen as a text file or an excel file from the interface. It records the input to the log file under four headings: The elapsed time, the type of the action and the X and Y values according to the mouse movements.

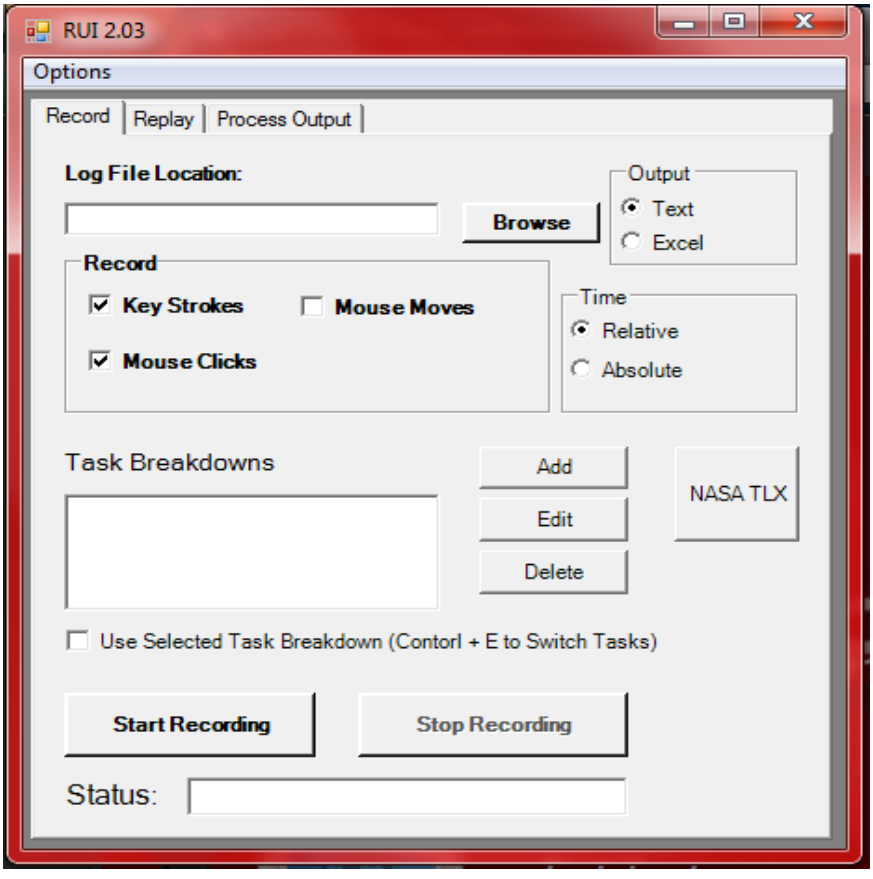


Figure C.1. RUI 2.03 Interface.

One can also choose the timestamp data to be relative or absolute. If it is relative the program logs the relative values within a minute as shown in Figure 50. For example, in Figure 50 first action is a click which is labeled as “Pressed” in the log file and it is attempted at the relative second 0.639 of the first minute. Second action is at second 34.881 and so on.

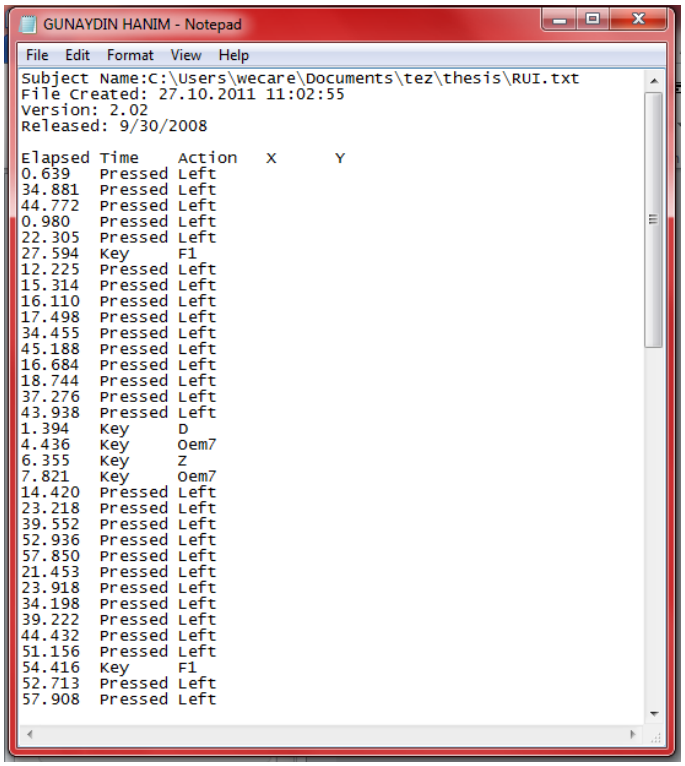


Figure C.2. RUI Log File (txt) with relative timestamp and no mouse movement.

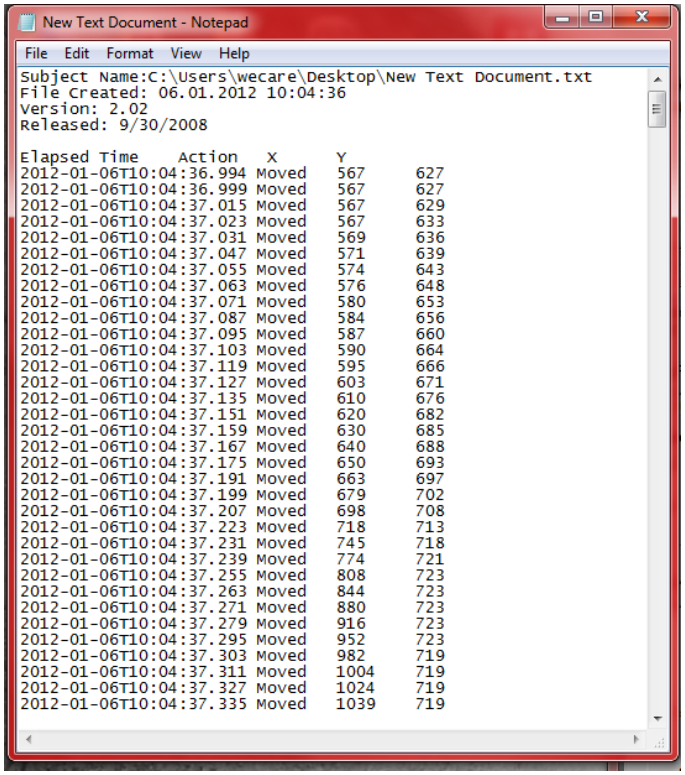


Figure C.3. RUI Log File (txt) with absolute timestamp mouse movement.

If the type of the time metric is selected to be absolute, the program records the exact time of the action (Figure 51). In addition, user can replay the loges action with a chosen speed which can be original, two times faster or slower.

22K/min amount of data is recorded with extensive mouse movements, but if the mouse movement is continuous, the amount of data can be as high as 156K/min [59]. The timestamp for a single keystroke is approximately 19 characters, so less mouse-intensive activities will have correspondingly smaller log files [59].

The data collected by RUI can be used for wide range of interfaces in order to measure user behavior and the time responses.

APPENDIX D: FORMULAS

Formulas for the calculations of complexity and hierarchy indices:

Let x_i denote the number of interface elements on the page i and p_t denote the number of pages required to complete a particular task t. Complexity index of a particular task t on an interface version, denoted as C_t, is given as:

$$C_t = \frac{\sum_{i=1}^{p_t} x_i}{p_t} \qquad \text{(D.1)}$$

Let also H_t denote the hierarchy index of a task t on an interface version. H_t is directly equal to p_t.

In order to calculate the complexity and hierarchy indices of the interface versions, let C and H denote the complexity and hierarchy indices of a version respectively. Then, C and H are simply calculated by taking the averages of the complexity and hierarchy indices (C_t and H_t) of the three tasks (phone, agenda and message):

$$C = \frac{\sum_{t=1}^{3} C_t}{3} \qquad \text{(D.2)}$$

$$H = \frac{\sum_{t=1}^{3} H_t}{3} \qquad \text{(D.3)}$$

F- value Calculations for ANOVA Test:

$$F = \frac{variance\ between\ items}{variance\ within\ items} \qquad \text{(D.4)}$$

$$F = \frac{\Sigma_i \; n_i(Y_i - Y)^2 \Big/ K\text{-}1}{\Sigma_{ij} \;\; (Y_{ij} - Y_i)^2 \Big/ N\text{-}K} \qquad \text{(D.5)}$$

where Y_i is the sample mean in the i^{th} group, n_i is the number of observations in the i^{th} group, and Y is the overall mean of the data, Y_{ij} is the j^{th} observation in the i^{th} out of K groups and N is the overall sample size.

APPENDIX E: BLUETOOTH PROGRAMMING

```
int nonin(HANDLE comport)
{
        char            INBUFFER[5000] = {'\0'};
        DWORD       bytes_read    = 0;    // Number of bytes read from port
        int             bStatus;
        DCB             comSettings;        // Contains various port settings
        COMMTIMEOUTS    CommTimeouts;
        k=0;


        /*Set timeouts in milliseconds*/

        GetCommTimeouts (comport, &CommTimeouts);
        // Change the COMMTIMEOUTS structure settings.
        CommTimeouts.ReadIntervalTimeout = MAXDWORD;
        CommTimeouts.ReadTotalTimeoutMultiplier = 0;
        CommTimeouts.ReadTotalTimeoutConstant = 0;
        CommTimeouts.WriteTotalTimeoutMultiplier = 10;
        CommTimeouts.WriteTotalTimeoutConstant = 1000;

        // Set the timeout parameters for all read and write operations
        // on the port.
        if (!SetCommTimeouts (comport, &CommTimeouts))
        {
          printf("SetCommTimeouts Error\n");
        }

         //Set Port parameters.

        if (GetCommState(comport, &comSettings)==0){

                printf("GetCommState Error\n");
        }
        else
        {
                memset(&comSettings,0,sizeof(comSettings));

                comSettings.DCBlength = sizeof(comSettings);
                comSettings.BaudRate = 9600;
                comSettings.StopBits = ONESTOPBIT;
                comSettings.ByteSize = 8;
```

```
comSettings.Parity   = NOPARITY;
comSettings.fParity  = FALSE;
comSettings.fBinary  = TRUE;
comSettings.fDtrControl = DTR_CONTROL_DISABLE;
comSettings.fRtsControl = RTS_CONTROL_DISABLE;


bStatus = SetCommState(comport, &comSettings);

try {
                if (bStatus == 0)
                {
                        printf("SetCommState Error...\n");
                }
                char buf[5];
                char buf2[5]={0};
                int t=0;
                DWORD read = 0;
                DWORD dwCommModemStatus;
                ofstream myfile;
                myfile.open ("oximetry.txt");

        SetCommMask (comport, EV_RXCHAR | EV_CTS | EV_DSR |
        EV_RLSD | EV_RING);
        while (comport != INVALID_HANDLE_VALUE){
                t=1;

                WaitCommEvent (comport, &dwCommModemStatus, 0);
                SetCommMask (comport, EV_RXCHAR | EV_CTS | EV_DSR |
                EV_RING);

                if (dwCommModemStatus & EV_RXCHAR)
                 {
                        // Loop for waiting for the data.
                        do
                        {
                         // Read the data from the serial port.
                         ReadFile(comport,buf,4,&read,NULL);
                         k++;
                         ;
                                DWORD i;
                                for(i=1;i<3;i++){
                                        buf2[i]=buf[i];
                                        buf2[i]=(buf2[i]+buf[i])/2;
                                }

                                if ((unsigned char)buf[0]>=160){

                                        goto ex;
                                }
```

```
                                        } while (read == 2);

                                    }
                                }
                                t=0;
                                ex:CloseHandle(comport);

                                myfile <<(int)buf2[1]<<"  "<<(int)buf2[2]<<endl;
                                printf("%d%d\n", (int)buf2[1],(int)buf2[2]);

                                myfile.close();
                                t=1;
                        }
                        catch( exception e)
                        {
                                CloseHandle(comport);
                        }
                }

 return 0;
}
```

Figure E.1: C++ code for Pulse-oximeter communicating via the Bluetooth.

REFERENCES

1. Kleinberger, T., M. Becker, E. Ras, and A. Holzinger, "Ambient Intelligence in Assisted Living : Enable Elderly People to Handle Future Interfaces", *Lecture Notes in Computer Science*, Vol. 4555, pp. 103-112, 2007.

2. Fisk, A. D., W. A. Rogers, N. Charness, S. J. Czaja, and J. Sharit, *Designing for Older Adults: Principles and Creative Human Factor Approaches*. New York, Taylor & Francis, USA, 2004.

3. Minichiello, V., L. Alexander, and D. Jones, *Gerontology: A Multidisciplinary Approach*, Prentice Hall, Sydney, 1992.

4. Kinsella, K., and D. R. Phillips, "Global Aging: The Challenge of Success", *Population Bulletin*, Vol. 60, No. 1, pp. 15-42, 2005.

5. Zejda, D., "Deep Design for Ambient Intelligence", in *2010 Sixth International Conference on Intelligent Environments*, pp. 277 - 282, 2010.

6. Wolf, P., A. Schmidt, and M. Klein, "SOPRANO – An Extensible, Open AAL Platform for Elderly People Based on Semantical Contracts 1", in *18th European Conference on Artificial Intelligence*, No. Ecai 08, 2008.

7. Broekens, J., M. Heerink, and H. Rosendal, "Assistive Social Robots in Elderly Care: A Review", *Gerontechnology*, Vol. 8, No. 2, pp. 94-103, 2009.

8. Hollinworth, N., "Improving Computer Interaction for Older Adults", *ACM SIGACCESS Accessibility and Computing*, No. 93, pp. 11-17, 2009.

9. McBryan, T., M. R. McGee-Lennon, and P. Gray, "An Integrated Approach to Supporting Interaction Evolution in Home Care Systems", in *Proceedings of the 1st ACM International Conference on Pervasive Technologies Related to Assistive Environments PETRA 08*, Vol. 282, pp. 1, 2008.

10. Newell, A. F., and P. Gregor, "Human Computer Interfaces for People with Disabilities", in *Handbook of Human Computer Interaction*, Vol. 1, Helander M. G., Landauer T. K., and Prabhu P. V., Eds. Elsevier Science B.V., pp. 813-824, 1997.

11. Chan, M., D. Esteve, C. Escriba, and E. Campo, "A Review of Smart Homes-Present State and Future Challenges", *Computer Methods and Programs in Biomedicine*, Vol. 91, No. 1, pp. 55-81, 2008.

12. Sneha, S., and U. Varshney, "Enabling Ubiquitous Patient Monitoring: Model, Decision Protocols, Opportunities and Challenges", *Decision Support Systems*, Vol. 46, No. 3, pp. 606-619, 2009.

13. Koch, S., and M. Hagglund, “Health Informatics and the Delivery of Care to Older People”, *Maturitas*, Vol. 63, No. 3, pp. 195-199, 2009.

14. Alemdar, H., and C. Ersoy, “Wireless Sensor Networks for Healthcare: A Survey”, *Computer Networks*, Vol. 54, No. 15, pp. 2688-2710, 2010.

15. Kartakis, S., and C. Stephanidis, “A Design-and-Play Approach to Accessible User Interface Development in Ambient Intelligence Environments”, *Computers in Industry*, Vol. 61, No. 4, pp. 318-328, 2010.

16. Abascal, J., I. Fernández De Castro, A. Lafuente, and J. Cia, “Adaptive Interfaces for Supportive Ambient Intelligence Environments”, *Interface*, pp. 30-37, 2008.

17. Xiong, M. W., and J., “A User Interface Level Context Model for Ambient Assisted Living “, *Lecture Notes in Computer Science*, Vol. 5120, pp. 105-112, 2008.

18. Zajicek, M., “A Methodology for Interface Design for Older Adults”, *Enterprise Information Systems Vi*, pp. 285-292, 2006.

19. Veldhoven, E. R. V., M. H. Vastenburg, and D. V. Keyson, “Designing an Interactive Messaging and Reminder Display for Elderly”, *Work*, pp. 126, 2008.

20. Goodman, J., and J. Lundell, “HCI and the Older Population”, *Interacting with Computers*, Vol. 17, No. 6, pp. 613-620, 2005.

21. Anastasia, G., "Newsletter SOPRANO 02", *SOPRANO*, 2010, http://www.soprano-ip.org, accessed at April 2011.

22. Lorenz, A., and R. Oppermann, “Mobile Health Monitoring for the Elderly: Designing for Diversity”, *Pervasive and Mobile Computing*, Vol. 5, No. 5, pp. 478-495, 2009.

23. Todd, C., and D. Skelton, "What are the Main Risk Factors for Falls Amongst Older People and What are the Most Effective Interventions to Prevent These Falls?", *World Health Organization*, 2004, http://www.euro.who.int/document/E82552.pdf, accessed at February 2011.

24. Zajicek, M., “Successful and Available: Interface Design Exemplars for Older Users”, *Interacting with Computers*, Vol. 16, No. 3, pp. 411-430, Jun. 2004.

25. Varshney, U., “Pervasive Healthcare and Wireless Health Monitoring”, *Mobile Networks and Applications*, Vol. 12, No. 2–3, pp. 113-127, 2007.

26. Alemdar, H. O., and C. Ersoy, “WeCare : Wireless Enhanced Healthcare”, in *12th Mediterranean Conference on Medical and Biological Engineering and Computing MEDICON*, pp. 1-4, 2010.

27. Wikipedia, *Graphical User Interface*, 2009, http://en.wikipedia.org/wiki/Graphical_user_interface, accessed at April 2011.

28. Häikiö, J., and M. Isomursu, "Touch-Based User Interface for Elderly Users", in *9th International Conference on Human Computer Interaction with Mobile Devices and Services MobileHCI*, pp. 289-296, 2007.

29. Hawthorn, D., "Possible Implications of Aging for Interface Designers", *Interacting with Computers*, Vol. 12, No. 5, pp. 507-528, 2000.

30. Kurniawan, S., A. King, D. Evans, and P. Blenkhorn, "Personalising Web Page Presentation for Older People", *Interacting with Computers*, Vol. 18, No. 3, pp. 457-477, 2006.

31. Grguric, A., I. Bene, S. Desic, M. Mosmondor, J. Krizanic, and P. Lazarevski, "Designing User Interfaces for Elderly : A Case Study in Applicability of Thin vs . Fat Clients", in *12th IEEE International Conference on e-Health Networking Applications and Services (Healthcom)*, pp. 99 - 105, 2010.

32. Ziegler, J., and J. Machate, "Integrated User Interfaces for the Home Environment", in *7th International Conference on Human-Computer Interaction*, pp. 807-810, 1997.

33. Höller, N., A. Geven, and M. Tscheligi, "Device and Interface Most Suitable for the Project HERMES", *HERMES Public Deliverables*, 2008. http://www.fp7-hermes.eu, accessed at May 2011.

34. Sutcliffe, A., "Investigating the Usability of Assistive User Interfaces" , *Interacting with Computers*, Vol. 15, No. 4, pp. 577-602, Aug. 2003.

35. Savitch, N., and P. Zaphiris, "An Investigation into the Accessibility of Web-based Information for People with Dementia", in *11th International Conference on Human Computer Interaction*, 2005, pp. 1-10, 1999.

36. Capitani, E., S. Della Sala, F. Lucchelli, P. Soave, and H. Spinnler, "Perceptual Attention in Aging and Dementia Measured by Gottschaldt's Hidden Figure Test.", *Journal of Gerontology*, Vol. 43, No. 6, p. P157-P163, 1988.

37. Pattison, M., and A. Stedmon, "Inclusive Design and Human Factors : Designing Mobile Phones for Older Users", *Human Factors*, Vol. 4, No. 3, pp. 267-284, 2006.

38. Nugent, C., M. Mulvenna, Fç Moelaert, B. Kareborn, F. Meiland, D. Craig, R. Davies, A. Reinersmann, M. Hettinga, A.-L. Andersson, R.-M. Droes, and J.E. Bengtsson, "Home Based Assistive Technologies for People with Mild Dementia", *Pervasive Computing for Quality of Life Enhancement*, Vol. 45, No. 41, pp. 63-69, 2007.

39. Nugent, C., R.J. Davies M.P. Donnelly, M. Hettinga, F.J. Meiland, F. Moelaert, M.D. Mulvenna, J.E. Bengtsson, D. Craig, and R.-M. Dröes, "A User Driven Approach to Develop a Cognitive Prosthetic to Address the Unmet Needs of People with Mild Dementia", *Pervasive and Mobile Computing*, Vol. 5, No. 3, pp. 253-267, 2009.

40. Mulvenna, M., F.J. Meiland, F. Moelaert, R. Castellot, J. Wallace, C. Nugent, S. Martin, R. Davies, and S. Devlin, "COGKNOW: Translating Research Innovation into Products and Services", *Dementia*, 2007.

41. Kline, D. W., and C. T. Scialfa, "Sensory and Perceptual Functioning: Basic Research and Human Factors Implications", in *Handbook of Human Factors and the Older Adult*, W. A. R. E. A D Fisk, Ed. Academic Press, 1996.

42. Cerella, J., "Age-related Decline in Extrafoveal Letter Perception.", *Journal of Gerontology*, Vol. 40, No. 6, pp. 727-736, 1985.

43. Potter, R. L., L. J. Weldon, and B. Shneiderman, "Improving the Accuracy of Touch Screens: An Experimental Evaluation of Three Strategies", *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems CHI 88*, pp. 27-32, 1988.

44. Jin, Z. X., T. Plocher, and L. Kiff, "Touch Screen User Interfaces for Older Adults: Button Size and Spacing", *Universal Access in Human Computer Interaction Coping with Diversity*, Vol. 4554, pp. 933-941, 2007.

45. Benko, H., A. D. Wilson, and P. Baudisch, "Precise Selection Techniques for Multi-touch Screens", *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems CHI 06*, Vol. 06, p. 1263, 2006.

46. Karat, J., J. Mcdonald, and M. Anderson, "A Comparison of Menu Selection Techniques: Touch Panel, Mouse and Keyboard", *International Journal of ManMachine Studies*, Vol. 25, No. 1, pp. 73-88, 1986.

47. Holzinger, A., "User-Centered Interface Design for Disabled andElderly People: First Experiences with Designing aPatient Communication System (PACOSY)", *Lecture Notes in Computer Science*, Vol. 2398, pp. 467-484, 2002.

48. Shneiderman, B., "Touch Screens Now Offer Compelling Uses", *IEEE Software*, Vol. 8, No. 2, pp. 93-94, 107, 1991.

49. Sears, A., and B. Shneiderman, "High Precision Touchscreens: Design Strategies and Comparisons with a Mouse", *International Journal of ManMachine Studies*, Vol. 34, No. 4, pp. 593-613, 1991.

50. Po, B. A., B. D. Fisher, and K. S. Booth, "Mouse and Touchscreen Selection in the Upper and Lower Visual Fields", *Proceedings of the 2004 Conference on Human Factors in Computing Systems CHI 04*, Vol. 6, No. 1, pp. 359-366, 2004.

51. Soprano Project, *End-users Throughout the SOPRANO' s Iterative Development Approach*, 2010, http://www.soprano-ip.org, accessed at April 2011.

52. Ellis, R. D., and S. H. Kurniawan, "Increasing the Usability of Online Information for Older Users: A Case Study in Participatory Design", *International Journal of Human-Computer Interaction*, Vol. 12, No. 2, pp. 263-276, 2000.

53. Miller, G., “The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information”, *Psychological Review*, Vol. 63, No. 2, pp. 81-97, 1956.

54. Farrington, J., “Seven Plus or Minus Two”, *Performance Improvement Quarterly*, Vol. 23, No. 4, pp. 113-116, 2011.

55. Byrne, M. D., “Computational Theory of Working Memory”, in *Conference Companion on Human Factors in Computing Systems*, 1996.

56. Saczynski, J. S., and G. W. Rebok, “Strategies for Memory Improvement in Older Adults”, *Topics in Advanced Practice Nursing eJournal*, 2004, http://works.bepress.com/jane_saczynski/17, accessed at May 2011.

57. Chikhaoui, B., and H. Pigot, “Towards Analytical Evaluation of Human Machine Interfaces Developed in the Context of Smart Homes”, *Interacting with Computers*, Vol. 22, No. 6, pp. 449-464, Nov. 2010.

58. Schedlbauer, M. J., R. L. Pastel, and J. M. Heines, “Effect of Posture on Target Acquisition with a Trackball and Touch Screen”, in *28th International Conference on Information Technology Interfaces*, 2006.

59. Kukreja, U., W. E. Stevenson, and F. E. Ritter, “RUI: Recording User Input from Interfaces Under Windows and Mac OS X.”, *Behavior Research Methods*, Vol. 38, No. 4, pp. 656-659, 2006.

60. Savitch, N., and P. Zaphiris, “Accessible Websites for People with Dementia : A Preliminary Investigation into Information Architecture”, *Lecture Notes in Computer Science*, Vol. 4061, pp. 144-151, 2006.

61. Newell, A., A. Dickinson, M. J. Smith, and P. Gregor, “Designing a Portal for Older Users: a Case Study of an Industrial/Academic Collaboration”, *ACM Trans ComputHum Interact*, Vol. 13, No. 3, pp. 347-375, 2006.

62. Zhang, B., P.-L. P. Rau, and G. Salvendy, “Design and Evaluation of Smart Home User Interface: Effects of Age, Tasks and Intelligence Level”, *Behaviour & Information Technology*, Vol. 28, No. 3, pp. 239-249, May 2009.

63. Thesaurus, *F-table (p=0.05)*, 2004, http://thesaurus.maths.org/mmkb/entry.html?action=entryById&id=1904, accessed at April 2011.

64. Block, B., “Understanding the Elderly”, 2011, http://www.asktheinternettherapist.com/articles/understanding-the-elderly, accessed at April 2011.